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VOLUME 14 JULY, 1940 NUMBER 4

PALEOECOLOGICAL FACTORS CONTROLLING THE DISTRIBUTION AND MODE OF LIFE OF CRETACEOUS AMMONOIDS IN THE TEXAS AREA[1]

GAYLE SCOTT

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ABSTRACT—This paper touches upon the growing importance of paleoecology. The classification of marine environments now in vogue with biologists is briefly reviewed and modified for geological and paleontological purposes. Two classifications are recognized. The habitat classification (planktonic, nectonic, necto-benthonic, benthonic) is used without reference to depth of water involved. It is concluded that most or all shelled cephalopods were mobile benthonic and necto-benthonic. The bathymetric classification refers to depth of bottom. Divisions recognized are: 1. littoral, 2. neritic (a. mud flat, b. reef, c. epineritic, d. infraneritic), 3. bathyal (a. epibathyal, b. infrabathyal), 4. abyssal.

It is suggested that the more obvious factors controlling ammonoid distribution may be interpreted in terms of morphology of shell, habits and distribution of living cephalopods, associated fossil faunas, types of sediments, paleogeography, bottom, and factors of the water medium such as salinity, temperature, depth, oxygen content, waves, currents. Flotation of shells after death of the animal probably occurred, but was much less important as a factor of distribution than is commonly supposed.

On the basis of shell morphology the principal Cretaceous ammonoid groups recognized are:

1. smooth, involute, obese (*Phylloceras*); 2. smooth, evolute, obese (*Lytoceras*); 3. smooth, ovate (*Desmoceras*); 4. sculptured, ovate to quadrate, a. medium sculpture (*Dufrenoya*), b. robust sculpture (*Mortoniceras*), c. obese, spinose (*Neocardioceras*); 5. tenuous, involute, lightly sculptured (*Oxytropidoceras*); 6. tenuous, involute, smooth (*Engonoceras*); 7. uncoiled types (several subdivisions, *Turrilites, Hamites*.

It is noted that ammonoids do not occur in littoral, mud flat, or reef deposits, and are rare with *Orbitolina*, rudistids and corals. Only the tenuous ammonoids (*Engonoceras, Oxytropidoceras*) are numerous with the abundant echinoids, oysters, and thick shelled gastropods and pelecypods of the epineritic zone. Sculptured forms of great variety and abundance occur in sediments deposited in the infraneritic zone (estimated at depths of 20–100 fathoms). Smooth, ovate genera (*Desmoceras*) lived in the epibathyal zone at or just below 100 fathoms. Smooth, obese genera (*Phylloceras, Lytoceras* and related forms) are found to the exclusion of other fossils in sediments of the infrabathyal zone. The Texas Cretaceous seas were too shallow to attract the smooth obese genera.

FEW INVERTEBRATE fossils have so captured the fancy of the naturalist, both professional and amateur, as the ammonites and nautiloids. Their strange shapes and great abundance over the extensive Mesozoic outcrops of Europe and the shores of the Mediterranean early brought their at-

[1] Presidential address fourteenth annual meeting of the Society of Economic Paleontologists and Mineralogists.

tention to civilized man and their dissimilarity to any other thing known to him naturally aroused his curiosity. The beginnings of stratigraphic geology are closely associated with regions of occurrence of ammonites and many stratigraphers have come to consider the ammonite the stratigraphic marker *par excellence*. The shells of these animals in fossil form have been the object of innumerable systematic and detailed studies so that today the most complex stratigraphic and phylogenetic classifications exist, and yet we are but little ahead of the ancients in our knowledge of the soft parts that occupied these shells in life, of the mode of life, or of the factors which controlled ammonoid distribution.

It is trite to call attention to the fact that such is the case because *Nautilus* is the only survivor of this great order, and that we do not know very much about either the habits of life or factors controlling the distribution of the four living species belonging to it. The vast suborder Ammonoidea has no living representatives, and the soft parts of these animals have never been found sufficiently well-preserved as fossils to give any very good idea of what they were like. We assume, and apparently with reason, that the ammonite body resembled the *Nautilus* and that when alive it breathed by four gills, but we do not know this to be a fact. With much less reason some of us postulate a hyponome for those ammonites whose shells are provided with the so-called hyponomic sinus. We leave that organ out of the soft parts of ammonites if the shell does not have such a sinus. The literature is replete with philosophical discussions of ammonite anatomy, even to the distinction between sexes. Some of these arguments are based on sound observation and reasoning; others would appear to be pure figments of the imagination. We do not even know that *Aptychi* and *Anaptychi* belonged to cephalopods at all, but we have good reason to think that they did. The reasons for their incredible abundance where ammonites are rare or absent; and their absence where ammonites are abundant is one of the most baffling puzzles in invertebrate paleontology. In spite of these gaps in our detailed knowledge of ammonite morphology we are reasonably safe in imagining a body not unlike that of the *Nautilus*, the anatomy of which, thanks to Owen and others, is reasonably well known.

The life habits of fossil cephalopods have provided almost as fertile a field for philosophical discussion as has morphology. Here again the four living species of *Nautilus* are a point of departure. Unfortunately, the mode of life of the *Nautilus* is far less well known than its anatomy. Even if the mode of life of these four species were thoroughly known it would be folly to suppose that all the great and varied hosts of fossil nautiloids and ammonoids lived after the same pattern. Voluminous literature has accumulated on the subject and in it many points of view have been expressed.

The older students of cephalopod phylogeny, like Hyatt (1884), were dominated by the theory of orthogenesis and the idea of racial senescence as expressed in the numerous and varied modifications of the cephalopod shell. Berry (1928) would have none of these ideas. According to his paper "The keynote of evolution of the hosts of extinct cephalopods . . . is adaptation."

Hyatt's views, of course, are based upon the biologically outmoded idea of racial senescence. Berry's view is more in accord with modern biological concepts. This is a difficult, even treacherous subject and while recognizing the fundamental soundness of the adaptive idea, some paleontologists are old-fashioned enough to cling to many of Hyatt's well thought-out concepts.

It appears to the writer that one of the phases of cephalopod study that has been almost entirely neglected is that of their paleoecological relationships, and the influence of such factors on their distribution. A. K. Miller and W. M. Furnish (1937) have recently published a stimulating discussion of the paleoecology of the Paleozoic cephalopods and there are numerous isolated ecological observations recorded in the literature, but no one has undertaken a serious paleoecological study of a Mesozoic area where a considerable variety of cephalopod material is found in some abundance. The Texas area would appear to be especially favorable for such a study. The rocks are in normal sequence, almost undisturbed over enormous areas. Successive formations often show little variation for great distances and yet the vertical variations from

formation to formation may be considerable so that many types of sediments are represented in the various formations. Fossils, including ammonites, are numerous in species and individuals. This paper purports to call attention to some of the possibilities in this field of research in the Texas Cretaceous.

Paleoecology is a science in which only the broadest outlines of procedure have been indicated and its possibilities of development would appear to extend without limit beyond the frontiers of our present knowledge. A worker in the field of marine paleoecology is at once aware of its complexity and of the special training and study required in it. Those who have not had thorough and extensive biological training, or who have not had the opportunity to observe the animals and plants of the seashore and of the shallow seas had best seek other fields in which to labor. Furthermore, paleoecology is so vast that the student must limit himself to some special phase of the subject, or to some area or group of animals. In this particular study, the factors of special interest, convenience and favorable conditions are the obvious limiting ones.

CLASSIFICATION OF MARINE ENVIRONMENTS

The fundamental classification of marine environments is complicated by the fact that it is designed primarily for the use of students of living forms. Its use is also made difficult because it is of necessity composed of two systems. Ordinarily marine forms are classified as *planktonic*, *nectonic*[2] or *benthonic*, depending on whether or not they float passively, swim directionally through the waters at various depths, or remain on the bottom. This may be termed a *habitat* classification, and is used without reference to the depth of the waters involved.

The other classification is on the basis of bottom depth and may be termed a *bathymetric* classification referring to the depth of the bottom from the surface. From the shallowest to the deepest these are usually termed *littoral*, *neritic*, *bathyal* and *abyssal*.

Each of these classifications is important and each is susceptible of innumerable subdivisions and refinements. Unfortunately, these terms are not standardized as to use so that each student finds it necessary to establish his own definitions, subdivisions and refinements. The writer's associate, W. G. Hewatt (1933), for example, in studying the benthonic animals of the sea, found a total lack of uniformity in definition of the littoral zone. According to his interpretation, it lies between the "normal high-water line of the spring tides and the normal low-water line of the spring tides."

In this study the following "habitat" classification will be followed:

1. *Plankton* is a term used for animals and plants which float, or swim passively at intermediate depths, or float at or near the surface in the seas.
2. *Necton* is a term which is used for organisms which swim directionally at intermediate depths.
3. *Necto-benthonic* organisms are those which hover over the bottom periodically swimming near the bottom and them coming to crawl or to rest upon it.
4. *Benthonic* is used to designate bottom living forms which may be (a) mobile benthonic, (b) sessile benthonic.

The following bathymetric classification is proposed for this study:

1. *Littoral* bottoms or deposits, refer to those which existed or were formed along shore between high tide and low tide. They are identified by well known characteristics.
2. *Neritic* bottoms are those between low tide and the 80–100 fathom line. It is possible to recognize several subdivisions in this group in Texas as follows:

a. *Mud flat* bottoms as defined here are somewhat more comprehensive than "mud flats" as commonly understood in most biological literature. As used here the term *mud flat* does not appear to apply to known modern seas of any considerable extent, but is believed applicable to certain ancient, extremely shallow, wide-spread and probably intermittent Cretaceous seas. The sediments are often muds or calcareous muds with occasional coquina limestones, all rich in marine fossils such as *Orbitolina*, large, thick-shelled gastropods and pelecypods. Sun cracks, animal tracks (dinosaurs of Cretaceous) are common. The water was probably reduced in salinity after heavy rains, and it is probable that at intervals these bottoms approached or even reached the exposed mud-flat stage over large areas. Ammonites are wanting.

b. *Zoogene* or reef bottoms, or deposits, are those formed by the remains of the usual reef-forming animals such as corals and rudistids. Reef deposits are extremely shallow in depth.

c. *Epineritic* or shallow neritic bottoms are characterized by quantities of echinoids, and a

[2] The term *pelagic* is here comprehensively interpreted to include the necton and plankton, but there is the greatest disparity in the use of pelagic in biological literature.

great variety of large, thick-shelled pelecypods and gastropods. The presence of broad pararipple marks and quantities of *Ostrea* and *Gryphaea* indicate that such bottoms did not exceed a depth of 20 fathoms. Certain types of ammonites are abundant. Others are wanting or rare.

d. *Infraneritic* deposits are composed of marls, shales, limestones, and arenaceous limestones. Their fauna is often rich and varied. Ammonities occur in profusion and variety. Algal remains and impressions are characteristic features indicating that neritic bottoms did not exceed a depth of 80–100 fathoms, or the maxmium depth of abundant photosynthetic plants.

3. *Bathyal* bottoms in the continental and adjacent seas range from depths of 80–100 fathoms downward. It is possible to recognize two subdivisions as follows:

a. *Epibathyal* sediments were deposited on bottoms at the limit or just below the limit of green plants. The sediments are marls and limestones. The fauna consists predominantly of certain types of ammonites. Gastropods are rare or absent. Pelecypod associations are likewise poorly developed.

b. *Infrabathyal* sediments were deposited in the depths of the geosynclines of continental seas. The fossils are often preserved in pyrite and the fauna consists almost exclusively of diagnostic ammonites. Algal remains and gastropods are not found. The bathyal bottoms must have been below the 100 fathom depth, that is well below the zone of light penetration sufficient to support green plants.

4. *Abyssal* deposits were presumably put down in the ocean depths. Since these are not subject to study they are of no importance here.

ANALYSIS OF POSSIBLE PALEOECOLOGICAL FACTORS CONTROLLING AMMONOID DISTRIBUTION AND MODE OF LIFE

There were probably a great many ecological factors affecting the distribution and manner of life of the ancient ammonoids of Texas and elsewhere. A preliminary analysis of these factors as far as they can at present be determined would appear to be fundamental to an understanding of the life habits of these ancient organisms.

The idea has prevailed pretty generally that the shells of dead ammonoids floated widely over the oceans to become entombed in sediments far from their native haunts. As a consequence, it was thought that the present distribution of the fossils gave only a poor idea of the distribution of these forms when alive.

In the writer's judgment the flotation idea has been given an emphasis far in excess of its importance. Willey (1902, pp. 717, 719, 726) and Rogers (1908, p. 461) mention that shells of *Nautilus* have drifted ashore in certain localities. It should be remembered, however, that *Nautilus* is used as food by the natives and many of the shells mentioned may well have been empty ones cast back to the sea by the inhabitants. There can be little doubt that flotation of ammonoid shells did occur, but shells which were transported to any considerable distance are likely to show the wear and tear incident to their voyage. There exists a number of ammonite localities in which a majority of the specimens are badly battered, thus indicating that they may have floated into a bay or eddy,[3] or were swept there by currents, tides or storms, but these are the exceptions rather than the rule. Possibly some chance finds of single specimens represent individuals which floated away from their habitat after death. There is every indication that flotation was not an important factor in the distribution of the fossil shells, and the collector who finds himself in the presence of considerable numbers of ammonoids in the field can be reasonably certain that their original inhabitants lived on the site.

Many factors controlling ammonoid distribution will probably never be known, and it is certain that none is now perfectly known. It would appear, however, that the more obvious factors may be grouped as follows:

1. Factors suggested by the morphology of the ammonite shell.
2. Factors controlling the life habits and distribution of the living Cephalopoda which may reasonably be expected to have influenced the fossil forms in similar manner.
3. Factors indicated by fossil faunas associated with the ammonoids.
4. Types of sediments in which ammonoids are most likely to occur, and their paleoecological significance.
5. Ammonoid habitats and their observed relationship to paleogeography.
6. Inferred and possible paleoecological effects of the water medium such as salinity, temperature, depth, oxygen, waves, currents, and bottom upon ammonoid life.

Factors suggested by the morphology of the ammonite shell.—The shells of Cretaceous fossil Cephalopoda present an almost in-

[3] Haug, E. *1920*, Traite de Geologie, lists a number of such localities where specimens were possibly accumulated in a given locality by flotation.

credible variety of form and sculpture. The principal features which group themselves in different combinations to produce great variety are as follows: whorl section, rate of whorl growth, degree of coiling (whether involute or evolute) if coiled, shape of shell as a whole if coiled, costation (whether absent or present, or if present whether coarse or fine, curved or straight, etc.), tuberculation, keeling, septal patterns, shell aperture, shell thickness.

The significance of none of these characters is particularly well understood and of some it can only be guessed. A few characters such as shell aperture and shell thickness are not readily observed in many specimens.

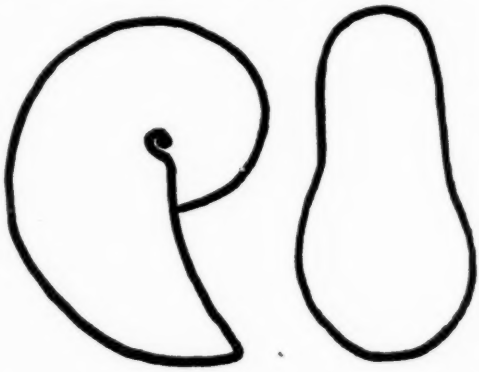

FIG. 1.—Outline drawings of *Phylloceras* illustrating the shell form and sculpture of amonites of group 1.

Shell aperture does not appear to affect very greatly the general shell shape but in certain instances may be suggestive of a mode of life. All other shell characters enumerated may be grouped to form the following principal shell types:

1. Smooth, involute, obese shells with circular or subcircular whorl sections as *Phylloceras* (fig. 1).

2. Smooth, evolute, obese shells with circular or subcircular whorl sections, such as *Lytoceras* (fig. 2), *Tetragonites, Gaudryceras, Kossmatella, Jaubertella, Silesites.*

3. Smooth, moderately involute shells with ovate or subquadrate whorl sections, as *Desmoceras* (fig. 3), *Uhligella, Beudanticeras, Latidorsella, Puzosia.*

4. Sculptured shells with quadrate to ovate whorl section. This group includes the vast majority of Cretaceous ammonite shells of the Texas area. Involution, whorl section and sculpture show almost infinite variety. On the basis of sculpture these may be divided into three large groups.

a. Shells with fine to medium sculpture consisting of fine to medium costae, tubercles, keels, etc. as *Dufrenoya, Hoplites, Parahoplites, Hypacanthoplites* (figs. 4c, d), *Sonneratia.*

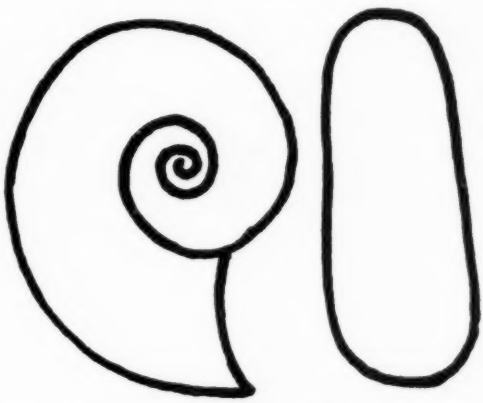

FIG. 2.—Outline drawings of *Lytoceras* illustrating shell form and sculpture of ammonites of group 2.

b. Shells with robust sculpture consisting of coarse, widely spaced costae and strong, bullate tubercles. Costae and tubercles are often of irregular shape and spacing. Examples are *Mortoniceras* (figs. 4a, b), *Dipoloceras, Mantelliceras, Prohysteroceras, Acanthoceras, Douvilleiceras* (figs. 4e, f), *Metoicoceras, Barroisiceras.*

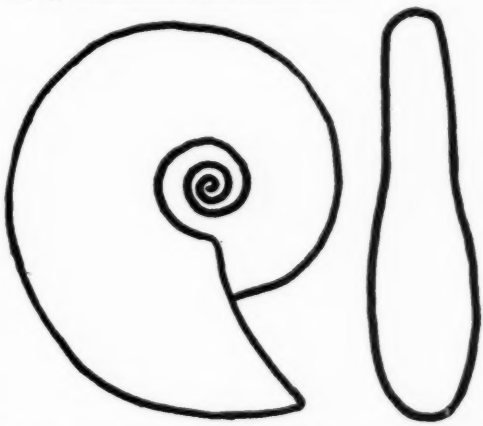

FIG. 3.—Outline drawings of *Desmoceras* illustrating shell form and sculpture of ammonites of group 3.

c. Obese, spinose shells represented by *Neocardioceras.*

5. Tenuous, involute, finely costate, nontuberculate, or only slightly tuberculate shells

with thin whorl sections, often strongly keeled. *Oxytropidoceras* (fig. 5) *Adkinsites, Manuaniceras, Venezoliceras* are examples of this type.

6. Tenuous, involute, smooth or with low, broad costae and tubercles. Whorl sections extremely thin, often truncate ventrally. *Engonoceras* (fig. 6), *Knemiceras, Placenticeras, Sphenodiscus* are representatives of this group.

7. Uncoiled or abnormally coiled forms in which a number of subtypes may be recognized:

a. Uncoiled, straightened, as *Baculites.*

b. Curved forms such as *Crioceras, Heliococeras, Allocrioceras, Exitelloceras.*

c. Partially uncoiled and hooked, as *Scaphites, Macroscaphites, Worthoceras, Hamites* (fig. 7a).

d. Spirally or irregularly coiled, represented by *Turrilites* (fig. 7b), *Bostrycoceras, Nostoceras, Nipponites.*

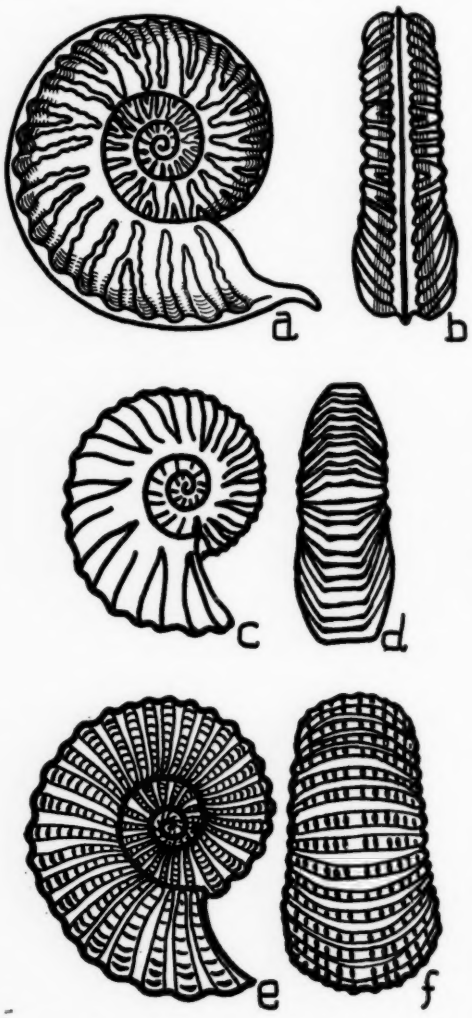

FIG. 4.—Outline drawings of *Mortoniceras* (*a, b*), *Hypacanthoplites* (*c, d*), and *Douvilleiceras* (*e, f*) illustrating shell form and sculpture of ammonites of group 4.

This is, of course, a thoroughly artificial grouping arranged for the convenience of this type of study. It is a sort of morphological grouping based on shell structure, and it is interesting to consider these types in relation to their possible habitats and modes of life.

It has been suggested that the obese, smooth-bodied forms lived at some depth where their obese shells would be adapted to resist a relatively high pressure, whereas the tenuous forms living at shallow depths would not be required to resist any considerable pressures. According to the pressure idea, the intermediate forms with ovate to quadrate and subquadrate whorl sections, often with robust sculpture or ornamentation, would fall in between these two extremes.

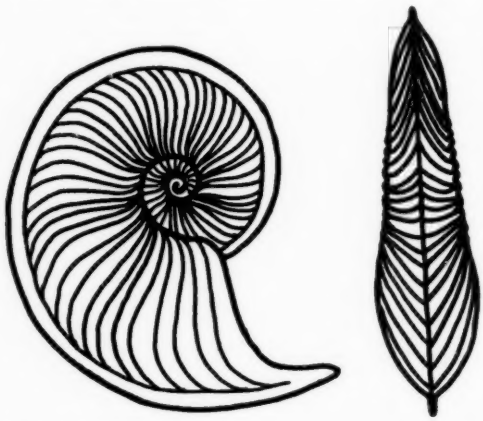

FIG. 5.—Outline drawings of *Oxytropidoceras* illustrating shell form and sculpture of ammonites of group 5.

The writer believes that, in general, obesity and smoothness of the ammonite shell together with thinness of shells indicate a depth habitat, and that tenuousness and relative smoothness and thick shells, indicate shallowness of habitat, but the problem is really very complex. There are many exceptions as there are to any general rule. *Vascoceras*, for example, is obese al-

though it is not particularly smooth. It appears to have lived in relatively shallow water and is here classified with group 4b.

It is dangerous to assume a bathymetric distribution of the ammonites on the basis of shell form alone. Probably, internal and external shell pressure tended to maintain a balance just as in modern fishes with swim bladders. There should be, therefore, no particular reason for the added strength of the obese form. Secondly, the idea does not appear to be supported by shells of modern mollusks, obese and tenuous types of which live more or less indiscriminately in shallow or deep water. Actually, most living mollusks with thin cross-section live in shallow water with their principal axis parallel to the direction of water movement in order to present as little resistance as possible to moving forces.

The thinking of investigators in this field has been strongly influenced by the idea that ammonoids must have filled all types of marine habitat. This is not necessarily

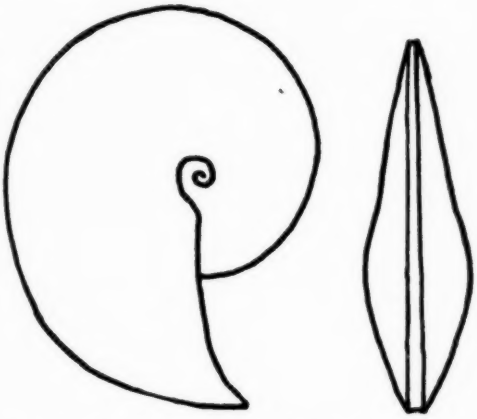

FIG. 6.—Outline drawings of *Engonoceras* illustrating shell form and sculpture of ammonites of group 6.

true. It is entirely possible that the ammonoids we know were adapted to only certain types of habitats. Their place in other so-called life zones might well have been taken by other cephalopods which had no shells, and some of these might conceivably have been tetrabranchiates. In this connection it is well to remember that modern shelled mollusks do not usually float and seldom are found swimming widely among the necton.

In any discussion of the life habits of marine organisms, it is important to keep in mind the distinction between the habitat

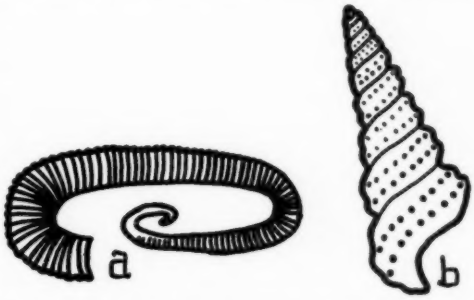

FIG. 7.—Outline drawings of *Hamites* (*a*) and *Turrilites* (*b*) illustrating shell form and sculpture of ammonoids group 7.

zones and the bathymetric zones just emphasized.

To state this point in another way: If shell modification indicates depth of ammonite habitat, should it be assumed that some species were planktonic, others nectonic, and still others benthonic? Or, were all or most of the ammonites of Mesozoic times benthonic or necto-benthonic, so that depth habitat corresponds to the bathymetric zones?

In this connection, it is interesting to examine Berry's (1928) diagram in which he postulates "adaptational modifications of the Cephalopoda with external shells." He emphasizes the significance of the supposedly gas filled chambers of the shells as agencies of buoyancy for the animal and distinguishes between suspended pelagic floaters, nectonic swimmers, and benthonic crawlers, pointing out the various shell adaptations favorable to each type.

Berry's arguments are put forward with considerable logic, and yet the writer does not believe that facts of ammonite habitat, ecology and distribution support his ideas conclusively. Berry calls attention to the contracted aperture of certain cephalopods with depressed whorls and suggests that this character was an adaptation to prevent the animal being dislodged from its shell, as the latter was dragged across the bottom. This is a character, however, of adult shells

and, if of importance in preventing such dislodging accidents, there should be considerable evidence in young fossil shells to indicate that their soft parts had been wrenched from them. Such is not the case. Furthermore, contracted apertures are characteristic of many ammonite species, some of which have depressed whorls, but many of which have compressed whorls. The writer has a single specimen in which the soft parts were evidently partially dislodged from the shell by a blow on what was then the posterior margin of the shell. The animal was partially rotated in its shell, became reattached and continued to grow for some time afterward. The ventral lobe of the suture lies on the ventro-lateral area of the shell. Incidentally, configuration of the shell grown after the accident was entirely normal. There is every indication that ammonites were held in their shells by strong muscular and other fleshy attachments. Reduced apertures of some sort are rather characteristic of most adult Cretaceous ammonites that the writer has been able to observe.

Other apertural characters which have given rise to much speculation are the so-called hyponomic sinus indenting the lip of many cephalopod shells, the greatly extended and often recurved ventral rostrum of other shells, and the various attitudes that the aperture may assume.

It has been common practice to correlate the hyponomic sinus with the presence of an efficient hyponomic funnel which expelled water forward thus serving to propel the animal backward after the manner of the modern squid. By correlative reasoning it has been assumed cephalopods, without this sinus, were not provided with a functional hyponomic funnel, probably did not have any other swimming organ and were, therefore, either crawlers or floaters.

Many Albian ammonites, notably the mortoniceratids and the oxytropidoceratids, had strong keels prolonged into curved or recurved rostra. Many lines of evidence indicate that all of these forms swam, at least moderately. This does not mean, however, that such types swam far and wide. Probably, even the good swimmers spent much of their time crawling on or hovering over the bottom, and seldom swam far from it. From a purely mechanical point of view there is no real reason why a rostrum should greatly interfere with a properly placed hyponomic funnel. Obviously the idea held by Hyatt (1894) and others that a shell devoid of a hyponomic sinus could not have harbored an ammonite capable of swimming needs drastic revision.

The writer cannot but feel that the sculpture of certain types of ammonites may suggest something of the nature of their habitat and mode of life. *Oxytropidoceras* is a superb example of the streamlining of an ammonite shell. Its ribs are small, steep anteriorly, gently sloping posteriorly and are curved far forward to merge with the sharp keel, but it is provided with a long slightly recurved rostrum which according to some would exclude any possibility of swimming. The shell form of *Oxytropidoceras* suggests a rather efficient backward swimmer. Other types of ammonites such as *Mortoniceras* and *Acanthoceras* do not exhibit this streamlined effect at all. They were probably awkward swimmers, although their predominant type of locomotion must have been crawling.

A few ammonites, such as *Neocardioceras*, were provided with long, inflexible spines, often longer than the diameter of the shells. *Neocardioceras* is an extremely globose shell. It is difficult to see how such an ammonite could have enjoyed any considerable freedom of movement of any kind.

Berry's diagram suggests a benthonic crawling existence for spirally coiled forms such as *Turrilites* and for irregularly coiled forms such as *Nipponites*, and the shells of these animals certainly suggest such an existence. It is not, however, a foregone conclusion that they were incapable of locomotion by the usual method of the hyponomic funnel. To the same author, shell forms exhibited by such genera as *Macroscaphites*, *Scaphites*, and *Heteroceras* suggest a sort of immobile and suspended floating, or planktonic existence, but at the same time he calls attention to "how cautiously shell form must be used in predicating locomotive ability." The writer is entirely in accord with this cautious interpretation. The form of shell of *Macroscaphites* is indeed suggestive of a pelagic, non-swimming existence, but aside from the fact that mollusks

provided with shells are very rarely pelagic, factors of distribution and associated animals are definitely opposed to such an existence for *Macroscaphites* and similar types. Rather a necto-benthonic crawling and swimming habit of limited extent is suggested for them.

In the complications of septal walls and resulting sutures, and in the wide variety of keeling found in many cephalopod shells the writer is unable to find a single suggestion of reflected surroundings. These structures are, no doubt, of fundamental significance, but all explanations of them so far advanced are little more than guesses.

Living cephalopods and possible ecological factors which they indicate for fossil forms.—Living Cephalopoda show almost infinite variety of body form and habit of life and yet there are considerable numbers of characteristics common to the entire group or at least to very large parts of it. Cephalopods range in size from minute forms to the giant squids which may reach an overall length of 52 feet (*Architeuthis princeps*, or Atlantic squid). Most modern Cephalopoda have no shells at all or only vestigial ones, but a few such as *Nautilus* are enclosed in shells of well known pattern. Their food is preponderantly, although not exclusively, composed of crustacea and small fishes. This single factor is an important one in limiting the distribution of modern cephalopods. Since this is a rather uniform factor we may reasonably assume that it had a similar limiting effect upon ancient forms such as the ammonites. Whales, sharks, and other large marine carnivora are their mortal enemies. The modern cephalopod in the vicinity of a whale or shark must have a much better chance of survival if he is on the bottom or if near enough to the bottom that he may get there quickly. The same was probably true for the ancient ammonites.

It is generally assumed that *Nautilus* among the living cephalopods most nearly parallels the ancient ammonites in habits and mode of life as well as in structure. Willey (1902, p. 698), to whose work reference is most frequently made concerning the living conditions suitable for *Nautilus*, simply says that traps are set at depths of 30 to 70 fathoms. His text, however, suggests that *Nautilus* may be found from depths of a few fathoms to indefinite depths. Julia Rogers (1908) states that it is found most abundantly at depths around 300 fathoms, but her work is not satisfactorily documented. Most texts and other papers which have discussed the modern *Nautilus* mention that it lives in relatively shallow water and yet very little actual data on this subject have been assembled. From the biological point of view, which takes into consideration the entire ocean, 300 fathoms is shallow. From the point of view of the geologist who has available for study only the sediments of the shallow epicontinental seas, 300 fathoms is decidedly deep.

According to all investigators *Nautilus* lives gregariously, swimming near or crawling on the bottom and the speed of movement is inconsiderable. Specimens have been reported floating at the surface, but according to most authorities such rare individuals are either sick or dead.

Sexes in all cephalopods are separate. In many groups sexual dimorphism is extremely pronounced. For example in *Argonauta* the females may be fifteen times as large as the males. The females also have shells and great enlargement of the dorsal arms which characters are not found in the males. It has been demonstrated that in most Cephalopoda the males are much less numerous than the females (hyperpolygynous). In *Nautilus*, however, sexual dimorphism is extremely slight and in *Nautilus pompilius* males seem to be more numerous than females (hyperpolyandrous).

Students of fossil cephalopods have been able to learn little if anything concerning the differences in sex in fossil ammonites and nautiloids. A few investigators have thought they might be able to identify sexes in certain ammonite species, but such findings proved difficult or impossible of demonstration. Markedly small and large sizes, obesity and thinness of marked extremes, and the like, in given species may mean that one group is male and the other female (in *Nautilus* the aperture is more flared in males than in females), but there appears to be no real way of knowing.

The sense organs, particularly those of equilibrium and of sight are well developed. Sight is an important factor in the life of

many modern cephalopods and was probably no less important in the lives of ancient types.

The modern Cephalopoda are exclusively marine animals. No authentic record exists of their habitual occupation of either fresh or brackish waters. They are occasionally carried by storms or currents into estuaries or other brackish water areas but cannot tolerate even slightly reduced salinity. There is every good reason to believe that such has always been the case with the cephalopods. Modern cephalopods can, on the other hand, tolerate saline conditions somewhat above normal, since they have been known to live in the Suez Canal where salinity is relatively high.

Many genera and quite a few species are cosmopolitan in their distribution. That certain ancient ammonites were similar to them in this respect appears to be well established. Some species have marked preference for the warm waters of tropical and sub-tropical areas whereas others prefer the colder waters. Thus the oigopsids *Cranchia scabra* and *Pyrgopsis pacificus* are found around the world in tropical and subtropical waters, but are not found in the higher latitudes.

A few cephalopods such as the larger decapods spend their lives swimming through the oceans at various depths. A few such as *Cranchia* (Oigopsida) are planktonic and float with the ocean currents. Some few species, notably of the Oigopsida dwell at considerable depths. *Spirula* 1000 fathoms, *Cranchia* and *Bathyteuthis* 1700, *Histiopsis* 2000, *Colliteuthis* 2200, *Cheiroteuthis* 2600 (Lankester, 1906). A number are luminescent. A very few such as *Sepiola* and *Rossia* are fossorial.

These habits of life are the exceptions rather than the rule. The vast majority of all modern Cephalopoda live an active and gregarious existence in relatively shallow water. Here they remain for the most part quite close to the bottom, crawling or resting on it, hovering or swimming just off of it. Except for *Nautilus* and a few others, they are, of course, without shells.

There seems to be every good reason to believe that the ancient ammonites, and probably the ancient nautiloids, of the Cretaceous of Texas lived after the fashion of most modern cephalopods: in relatively shallow water, probably for the most part in droves, crawling upon, or hovering and swimming just above the bottom in areas where food, in the form of crustacea and small fishes, was abundant. There is no evidence that they ever lived in fresh or even brackish water. There may have been forms without shells which were planktonic floaters, but evidence will be presented to show that none of the shelled species which have thus far been postulated as floaters were such in reality. So far as the writer is aware, there is no evidence whatsoever to indicate that any ammonite was ever a burrower. There may have been ammonite inhabitants of the deep seas, but sediments of the ancient ocean depths are not known to us.

Of the eggs and developing young of most Cephalopoda, very little, unfortunately, is known. The eggs of those whose breeding habits are known are normally laid inshore, singly or in clusters, and are usually fastened to the bottom in some way. The eggs are distinctive on account of their large quantities of yolk. Brooding over the eggs by the females takes place in some species. A thorough study of the embryology and behavior of the young of the modern Cephalopoda, particularly *Nautilus*, might be of inestimable value in deciphering the life secrets and relationships of the ancient cephalopods, but these data are yet to be assembled.

Cephalopod eggs, whether single or in clusters, are united in a continuous cellular follicle. Copulation takes place, usually by a hectocotylised arm, which may be caducous. A few such as *Argonauta* are viviporous, but in most species, the eggs are deposited after fertilization and the young are not nurtured. The number of eggs laid is extremely variable (*Loligo*, 40,000). The larvae of cephalopods are not trochospheric, but the young hatch out to resemble the adults very closely. The period of incubation is variable, but considerably longer than in other mollusks. The habits of the larvae are little known, and in most species do not appear to be markedly different from the adult. The marine larvae of temperate seas are relatively intolerant of temperature rises, thus excluding the cephalopods from shallow waters which may suddenly become

warm. There is little doubt that the larvae of the ancient ammonites were similarly sensitive to temperature changes, and this factor can conceivably have affected their distribution.

Factors indicated by fossil faunas associated with the Ammonoidea.—Miller and Furnish (1937) and others have called attention to the possibility of deriving considerable information concerning the paleoecology of a group of organisms from a study of the associated fossils. In the writer's opinion the value of this type of attack in studying the paleoecology of a group such as the cephalopods cannot be over emphasized. It is a method of study, however, which encounters numerous difficulties and which, if not employed with the greatest caution, may easily lead to serious inaccuracies. For example, it may be that a given ammonite fauna is limited to a definite stratum of only a few inches thickness in a formation where other fossils are found throughout. In such a case it is important to delimit the faunas associated with the ammonites to those species actually found in the ammonite bearing ledge. For purposes of paleoecology, it is necessary to recollect most localities with the idea of definite associations in mind. Since this has not been the general practice, published lists of faunas for many formations are useless in paleoecological studies.

It is well known that Cephalopoda do not commonly occur in association with certain types of marine fossils, and observations calling attention to this discrepancy in their occurrence are abundantly recorded in the literature. Foerste (1936) has stated that where early Paleozoic cephalopods are abundant the mobile gastropods are likely to be abundant, but the sedentary brachiopods, corals, and bryozoans will probably not be found in quantities. A. K. Miller and Furnish (1937), however, have observed that "in the Upper Ordovician of the northwestern United States the remains of nautiloids, mobile gastropods, and corals very commonly occur together," and call attention to the fact that such an association is particularly noticeable in near-shore deposits such as the Lander sandstone of the Big Horn formation. These writers also make the statement that "in the Early Paleozoic deposits cephalopods are commonly found associated with heavy-shelled benthonic animals, indicating that the entire fauna lived in relatively shallow water." These statements refer, of course, to older Paleozoic nautili. The Cretaceous cephalopods, and particularly the ammonites, are infinitely more variable than the Paleozoic nautiloids, and individual species were apparently much more sensitive to their environment.

It is not a new observation to point out that in Texas ammonites are rarely found associated with the remains of reef-building animals of any kind. Only accidental finds of ammonites associated with rudistids, reef-building corals or large Foraminifera such as *Orbitolina*[4] have ever been recorded, and ammonites did not appear to favor the brachiopod habitat. Likewise, most ammonites are not found abundantly along with plentiful representatives of the echinoderm phylum, although certain ammonoid species (notably flat, thin, little-sculptured species) may be numerous. Incidentally, F. B. Plummer, R. C. Moore and the writer in collecting ammonoids and crinoids in the Texas Pennsylvanian have learned to look for these two types of fossils in different stratigraphic units. Pennsylvanian ammonoids seldom are found with fusulinids.

The Glen Rose formation outcrops over enormous areas in Texas and parts of Arkansas. Its extensive exposures are always richly fossiliferous. Rudistids such as *Monopleura*, *Toucasia*, and others are numerous at certain levels. *Orbitolina* is abundant but restricted to certain levels. Oysters of many genera and species are well represented and often occur as fossil oyster beds with less abundant specimens scattered throughout the formation. So far as the writer is aware, no cephalopod has ever been found in the Glen Rose rudistid, or *Orbitolina* beds, and they are rare in oyster beds. Most of the Glen Rose clays, shales and limestones carry numerous specimens of many species of large, thick-shelled pelecypods and gastropods, and some levels are rich in echinoids, Bryozoa and reef-forming corals. Throughout these strata, except in

[4] The writer understands that abundant ammonites and *Orbitolina* have been found closely associated in Cretaceous rocks in Arabia.

west Texas where conditions are different, cephalopods, with the exception of the thin-bodied, little-ornate type such as *Knemiceras*, are of accidental occurrence. Most cephalopods apparently could not endure the environment favored by such types as the rudistids, corals, Bryozoa, *Orbitolina*, *Ostrea* and the large thick-shelled pelecypods and gastropods. It is not known if these types were in themselves obnoxious to the ammonites. More probably, such factors as the shallowness of the water, or the variability in salinity, or the extremes of temperature of such waters were not favorable to them or to their eggs and larvae.

In extreme West Texas in the center of the old geosynclinal area now occupied by the Quitman Mountains and extending southeastward into Mexico there are thick Glen Rose strata in which rudistids, corals, orbitolinas, and oyster beds are not found, and echinoderms and large thick-shelled gastropods and pelecypods are rare. In these strata a rich cephalopod fauna has been found. All the species described belong to what, in this study, is called the sculptured type (group 4) with quadrate to ovate whorl sections such as *Dufrenoya*, *Hoplites*, *Parahoplites*, *Sonneratia*, *Douvilleiceras*, *Trinitoceras*, *Hypacanthoplites*. Thin-bodied, little-ornate types such as *Knemiceras*, *Pseudosaynella* and the nautiloid *Vorticoceras* have not been found in these strata.

The Fredericksburg group of strata (Middle Albian) in Texas is remarkably uniform over wide areas. The group typically comprises the Walnut Shell Bed (*Exogyra* and *Gryphaea*); the Comanche Peak strata composed of shales, clays and white nodular limestones; the Edwards limestone and the Kiamichi clays. North of the Brazos River the combined Comanche Peak and Edwards strata constitute the Goodland formation.

The Walnut shell beds yield occasional ammonites, but so far as the writer is aware, all the specimens that have ever been found in these strata are of the thin-bodied little, ornate type belonging to the genera *Oxytropidoceras* and *Engonoceras*. Specimens of these genera are often found incorporated in the broadly rippled shell beds with many shells attached.

In the Comanche Peak clays, shales and nodular limestones, ammonites are almost unbelievably abundant, but with the exception of a *Hamites*, a few specimens of *Dipoloceras* and two or three as yet unidentified fragments, the many Comanche Peak specimens all belong to the thin-bodied, lightly-sculptured genera such as *Engonoceras*, *Oxytropidoceras*, *Venezoliceras*. The associated fossils are incredible numbers of echinoids, oysters and oyster beds, corals, worms, and a bewildering array of large and small thick-shelled gastropods and pelecypods.

At three localities in the Goodland the writer has taken at random three areas of 144 square feet each and has counted 6, 7, and 14 specimens of tenuous ammonites in them. No other cephalopods were found. Each of the squares yielded more than 100 echinoids, more than 100 large, thick-shelled gastropods (*Natica*, *Tylostoma*, *Nerinea*) and pelecypods (*Cyprimeria*, *Protocardia*, *Trigonia*, *Pholadomya*) several solitary corals, oysters and incredible numbers of *Gryphaea*. In one *Gryphaea* shell bed three inches thick, twelve large ammonites were counted in a distance of 15 feet. Numerous *Gryphaea* and *Ostrea* adhered to the cephalopods.

Assuming that these Cretaceous organisms lived at depths inhabited by corresponding modern types the ancient Albian seas of Texas which the tenuous ammonites found so hospitable, must have been, for the most part, less than 20 fathoms in depth.

The Edwards is essentially a reef limestone[5] composed in many places of rudistids (*Monopleura*, *Taucasia*, *Caprina*, *Caprinula*, *Biradiolites*), corals, large and thick-shelled gastropods and pelecypods and other bizarre types. There are no ammonites.

The Kiamichi is a clay with a few thin beds of yellow nodular limestone and many thin beds of sandy flagstones. The fauna is not especially varied. The principal elements are *Gryphaea* and other oysters, *Trigonia*, *Arctica*, *Protocardia*, *Inoceramus*, and a few other large clams and some gastropods. Thin-bodied, lightly-sculptured ammonites such as *Oxytropidoceras*, *Manuaniceras*, and *Adkinsites* are abundant. In the

[5] "Bioherm" and related terms proposed by Cummings (1932) are lacking in the specific meaning required for use here.

uppermost levels a few specimens of *Elobiceras* (quadrate whorls with robust sculpture) and possibly related genera have been collected.

The Middle Albian of other regions than Texas has yielded some of the richest and most varied ammonite faunas known from any strata, and it is therefore singular that these strata in Texas should have yielded almost exclusively the tenuous, smooth and little-sculptured forms. It would appear that an environment favored by oysters, echinoids and large, thick-shelled pelecypods and gastropods was unfavorable to practically all Albian ammonites except the tenuous, little-ornamented types. The reef habitat was not favorable at all to Middle Albian ammonites.

The Washita (Vraconnian, Upper Albian) group of sediments in Texas is extremely variable and its ammonite fauna, much in need of monographic study, is especially interesting. In the typical North Texas area the succession of formations recognized is as follows: Duck Creek, Fort Worth, Denton, Weno, Pawpaw, Mainstreet, Grayson.

The lower half of the Duck Creek is a veritable bonanza of ammonites and the dominant type is the large, smooth, moderately evolute shell with ovate to subquadrate whorl-section exemplified by *Desmoceras*, *Uhligella*, etc. Around Fort Worth thousands of these shells have been collected for rock gardens, fences, fireplaces, and posts in the parks. The writer knows of small streams where one may walk for several yards stepping from one to another of these large specimens. Associated with these smooth, ovate-whorled forms are numerous other species belonging principally to quadrate-whorled, robustly sculptured types such as *Mortoniceras Prohysteroceras*, *Hamites*. Most of these species are large. Fossils, other than ammonites, are not numerous in the lower Duck Creek. *Inoceramus* is frequent, an occasional echinoid is found, but gastropods are rare and small in size, and the limited numbers of pelecypods found are small and thin-shelled. Scarcity of algal remains and the rarity of gastropods suggests that these strata may have been deposited at or possibly below the limit of green plants, that is, below a depth of 80–100 fathoms.

In the upper Duck Creek marls the fauna is more varied. Ammonites are still predominant at most levels, but the variety is considerable and the smooth forms with ovate whorl sections such as *Desmoceras* are not the principal element of the fauna. In Tarrant County the brachiopod *Kingena wacoensis* occurs in great profusion through a narrow thickness. Ammonites are rare or absent in this zone. At one locality in Fort Worth the small echinoid *Goniophorus scotti* Lambert is found in great numbers, but occurs only in a narrow radius. Other echinoids, however, are not uncommon in the upper Duck Creek over wide areas. *Gryphaea* occurs in some abundance and there are several other species of pelecypods and a few species of gastropods. For the most part these are relatively small and thin-shelled types, and they are not numerous either in species or individuals.

The cephalopods are represented principally by several species of *Mortoniceras* and *Prohysteroceras*, but *Desmoceras* and *Uhligella*, occur sparingly. *Scaphites*, *Worthoceras*, *Hamites* and *Crioceras* are important elements of the fauna.

An interesting feature of the upper Duck Creek fossils is the preservation of many of them in pyrite and marcasite. The ammonites, of course, are particularly adapted to this type of preservation, but many small gastropods, pelecypods and even echinoids are also preserved in this manner. The pyrite ammonites are all small, and were once described by the writer (1924) as a dwarfed fauna. Many of them are indeed small species as indicated by adult specimens of *Worthoceras* and *Scaphites*, but it is probable that many of them are the preserved inner whorls of large specimens.

In connection with this "pyrite fauna" it is worthy of note that in the marly formations in the centers of deep ancient geosynclines the faunas are composed almost exclusively of the smooth, obese types of ammonites, often preserved as pyrite pseudomorphs. The writer, however, has examined a number of these faunas from such regions as the Alps and has noted certain differences in their character. In addition to being predominantly smooth, obese forms, the Alpine specimens are larger than the Texas pyrite forms and obviously are the pre-

served inner whorls of relatively large individuals. The Texas pyrite faunas such as are found in the upper Duck Creek, Denton, Pawpaw and Grayson do not contain the smooth, obese ammonites, but are composed largely of mortoniceratids, scaphitids, desmoceratids, turrilitids, hamitids, etc., and even engonoceratids. Many of them are obviously dwarfed, and the faunas contain many elements besides ammonites, such as echinoids and considerable varieties of gastropods and pelecypods.

The ammonites of the Fort Worth formation are predominantly of the types characterized by robust sculpture, and quadrate to subquadrate whorls. They are for the most part mortoniceratids. Associated with them are abundant and varied pelecypods and gastropods some of which are moderately large and thick shelled. Echinoids, though not abundant as measured by the standard of the Goodland, are plentiful. Large oysters and worm tubes are also common. A notable feature of the Fort Worth is that many of its limestone ledges are veritable masses of supposed algal material ordinarily referred to as "fucoids," but the specimens are not really determinable.

The Denton is a marly clay, topped by a *Gryphaea* and oyster shell bed. Ammonites are not abundant, but on the Red River where the formation is thickest they are sparingly found in the lower clays. They are predominantly mortoniceratids and are preserved as pyrite pseudomorphs. Small crustacea, *Gryphaea* and *Ostrea* are in closely associated strata.

The Weno ammonites are mainly mortoniceratids and are reasonably abundant. They are accompanied by a varied fauna of echinoderms, the large foraminifera, *Haplostiche*, and numerous pelecypods and gastropods. The large, thick-shelled pelecypods and gastropods, however, are not found or rare.

The Pawpaw is best developed near Fort Worth and contains a pyrite fauna of striking variety. Turrilitids, mortoniceratids, scaphitids, hamitids and engonoceratids are abundant. A rich fauna of small echinoids, small gastropods and pelecypods, sharks teeth and vertebrae, and crustacean parts accompany these cephalopods. Algal remains are a prominent part of calcareous flagstone layers.

The cephalopod remains in the Main-street limestone are almost exclusively turrilitids of large size and the large *Nautilus texanus* which is found sparingly throughout the Washita group of sediments. Other cephalopods of robust sculpture and quadrate whorl section are occasionally found. The other fauna is not conspicuous, but echinoids, oysters, pelecypods and gastropods are found.

The Grayson presents another zone of pyrite faunas and their constitution is similar to that of the Pawpaw faunas. Turrilitids, scaphitids, engonoceratids and the mantelliceratids are the predominant cephalopods. Other fossils are small gastropods and pelecypods, and echinoids. Toward the top of the formation the strata become more calcareous; oysters, such as *Gryphaea* are more numerous; pectens of large size, large pelecypods, gastropods and echinoids are common. The only ammonites found in any abundance in these upper strata are *Engonoceras* (tenuous, little-sculptured), *Stoliczkaia* (robustly sculptured, subquadrate whorl section) and *Turrilites*.

The Woodbine sand was deposited probably as a river delta, and along the outcrop is composed of non-marine and brackish water deposits. Land plant fossils are found at some levels, and there are occasional strata bearing brackish water mollusks. No cephalopods have been found in the Woodbine.[6]

Over much of Texas the Eagle Ford group and its equivalents reach thicknesses of 300 to 500 feet. Ammonites occur in considerable abundance at several levels and sporadically throughout the group. The strata have also yielded a rich fauna of other mollusks, Foraminifera and Ostracoda, but these fossils have not been adequately collected with a view to determining their association with the ammonites within definite stratigraphic limits. It is, therefore, difficult to speak with any degree of accuracy concerning the species which are associated intimately with the ammonites. There are, however, at least three zones where ammonites are relatively abundant and in which, thanks to W. L. Moreman (1927), the asso-

[6] *Acanthoceras wintoni* Adkins (Univ. Texas Bull. 2838, p. 244) reported from the Woodbine, is certainly from the Eagle Ford.

ciated faunas are known with some accuracy.

The lowest of the zones is the so-called *Acanthoceras* zone. In Tarrant and neighboring counties this zone is especially well developed and appears to extend southward as far as Bell County (Adkins, 1930) and northward to the Red River. In the section it lies in the calcareous marls and clays immediately above the massive sandstones and oyster beds ordinarily known as the Lewisville beds of the Woodbine, but believed by many to be of Eagle Ford age. To the south in Johnson County and beyond, specimens are sometimes found in the flaggy sandstones at the base of the marls. Acanthoceratids (quadrate whorls, robust sculpture) are the abundant ammonites in this zone but an engonoceratid (*Epengonoceras dumbli*) is occasionally found. In this ammonite zone the large and beautiful *Arca tramitensis* and a small undescribed *Exogyra* occur in great abundance. Just under the zone is a bed in which shark teeth of the so-called "pavement" variety abound. Other pelecypods and gastropods are found in the zone, but they are neither varied nor abundant.

The next zone of abundant ammonites occurs near the middle of the Eagle Ford group in dark to black laminated shales with iron-clay-stone concretions. The ammonite fauna is prolific and varied. The dominant types are the robustly sculptured forms with quadrate whorls represented by many species of *Metoicoceras* (group 4b), thin-bodied involute smooth forms represented by several species of *Placenticeras* and *Protengonoceras* (group 6), obese, irregularly costate and strongly spinose forms represented by *Neocardioceras* (group 4c) and a great variety of uncoiled and abnormally coiled forms represented by the straightened *Baculites* (group 7a), the curved and slightly spiral *Exitelloceras* (group 7b) and the partially uncoiled and hooked types represented by several species of scaphitids (group 7c). The preservation of these fossils is often remarkable.

The fauna associated with the middle Eagle Ford ammonoids is not particularly striking. *Inoceramus*, represented by several species, all of relatively small size, is perhaps the most noticeable molluscan element. A few other pelecypods and gastropods are found in considerable abundance preserved in the concretions with the cephalopods, but they have no particularly definitive characteristics. Remains of small and large fishes and sharks are plentiful, and a few remarkably well preserved specimens of fish have been found. These beds have also yielded the teeth, vertebrae, and even complete skeletons of the marine reptile *Mososaurus*.

Some hundred feet below the top of the Eagle Ford there are thin beds of flaggy, arenaceous limestones which outcrop to form a low scarp on the otherwise flat to slightly rolling Eagle Ford terrain. In places these strata carry abundant ammonoids, but elsewhere appear to be barren. The principal types are prionotropids, forms with quadrate whorls extremely robust sculpture (group 4b), but genera, of other similar groups and uncoiled forms also occur. The fauna is in need of adequate analysis and description. Associated with these ammonites are incredible numbers of small to medium sized *Inoceramus*, gastropods, scaphopods, limpet-like shells and quantities of fish remains such as scales and teeth, and the bones of *Mososaurus*.

It is notable that nautiloids have not been found in the Eagle Ford. A few heavy-bodied ammonites of the pachydiscid type (group 3) have been collected in the strata, but they are definitely rare.

The Austin chalk carries a rich fauna, but unfortunately it has been little studied. The principal cephalopods are the globose nautiloids, *Eutrephoceras dekayi* and related species, ammonites of the group of *Ammonites texanus* and *Barroisiceras* (robust sculpture, quadrate whorls, group 4b), *Placenticeras* (group 6), *Pachydiscus* and *Parapuzosia* (group 3). *Baculites* (group 7a) and *Scaphites* are also well represented. *Pachydiscus* and *Parapuzosia* are not numerous in the Austin chalk except in southwest Texas near the Rio Grande where *Parapuzosia* is represented by the giant species *P. americana* and *P. bösei*. The principal associates of the Austin chalk ammonites seem to have been incredible numbers of *Inoceramus* belonging to many large and small species. Large specimens of rudistids belonging to *Durania* and related genera are also found in the chalk, but they are not in reefs, and whether or not the specimens occur in the

same strata with the ammonites is not known. Other mollusks and considerable numbers of echinoids are also found, but the degree of their association with the cephalopods is yet to be worked out.

The cephalopod fauna of the Taylor, as yet poorly known, does not appear to present ecological features differing appreciably from those of the Austin chalk. The principal types are placenticeratids (tenuous, smooth, group 6) *Prionocyclus* (robust sculpture, quadrate whorls, group 4b), *Baculites* (group 7a) and *Scaphites* (group 7c). In South Texas in Medina and neighboring counties the Taylor has yielded pachydiscids, *Puzosia* and *Parapuzosia* (group 3). In all cases *Inoceramus* is abundantly associated with these ammonites, but other associated fossils are as yet poorly known.

In the Navarro and its equivalents ammonoids are often abundant at certain levels. The dominant genera are perhaps *Sphenodiscus* and a relative *Coahuilites* (tenuous, smooth, group 6). Along the Rio Grande, 15–18 miles below Eagle Pass in Texas and in Mexico, the writer has collected species of these genera in unbelievable numbers, and they are almost the only cephalopods to be found in the strata. In close association with them are rich faunas composed of oysters and a great variety of large pelecypods and gastropods.

In the Nacatoch sands in Hunt County *Sphenodiscus* and *Baculites* are associated with quantities of *Belemnitella americana*. Other mollusks include *Ostrea*, *Exogyra* and a variety of pelecypods and gastropods, mostly of the large, thick-shelled types. In the same sands near Corsicana and at Chatfield *Sphenodiscus* occurs associated with abundant specimens of the strange irregularly coiled *Nostoceras*. Occasional pachydiscids are found but they are rare. Medium-sized pelecypods and gastropods, especially *Cucullaea* and *Turritella* are abundant.

From this short review of principal types of cephalopod faunas found in the Cretaceous of Texas it is observed that the smooth, involute, obese forms with circular whorl sections (group 1), and the smooth, evolute, obese shells with circular whorl sections (group 2) are not found. The smooth, moderately involute shells with ovate to subquadrate whorl sections such as *Desmoceras* and *Puzosia* (group 3) are found at several levels, but only in the Duck Creek limestone of the lower Washita are these types abundant enough to constitute the dominant element of the fauna. Here they are associated with a few specimens of *Hamites*, *Mortoniceras*, *Prohysteroceras* and *Inoceramus*. Echinoids and the usual types of pelecypods and gastropods are almost entirely lacking.

Shells with fine to medium sculpture, quadrate to subquadrate whorl sections (group 4a) are the predominant types found in the Travis Peak formation (lower Trinity) of Central Texas and in the marly clays and shales of Glen Rose age in the Quitman area of West Texas. Echinoids, the large, thick-shelled pelecypods and gastropods and oysters are found, but they are not abundant. Medium-sized gastropods and pelecypods are plentiful.

The heavily sculptured ammonites with quadrate whorl sections (group 4b) are the most common types found in Texas. Their dominance is particularly well demonstrated in the Washita (except lower Duck Creek), Eagle Ford, and Austin chalk. With them are a few of the moderately involute forms with ovate whorl sections (group 3) and the thin-bodied smooth types (group 6), but these have a minor role in such faunas. The various uncoiled types (group 7) are often present in considerable numbers. Associated with these ammonoids are the usual run of pelecypods and gastropods, but the large, thick-shelled types and oysters are rarely found, and echinoids are never abundant. The extremely spinose type represented by *Neocardioceras* (group 4c) is found only in the Eagle Ford associated with *Metoicoceras*, *Placenticeras* and uncoiled types.

The tenuous, involute, finely costate, nontuberculate or only slightly tuberculate type (group 5) is found abundantly in the Fredericksburg rocks. The only other types of ammonites occurring in any abundance with them are the thin-bodied, smooth engonoceratids. Associated with these ammonites are astounding numbers of echinoids, oysters and a great variety of thick-shelled gastropods and pelecypods, worm tubes, corals, and crustacean fragments.

The tenuous, smooth ammonites (group

6) are found to the approximate exclusion of all others in the Glen Rose of the greater area of Texas and at many places in the Escondido (Navarro). Associated with them are quantities of large, thick-shelled gastropods and pelecypods. Bryozoa, worm tubes, corals, echinoids and oysters are abundant. The tenuous, smooth ammonites are also found in great abundance in the Fredericksburg, but their position is subordinate to that of the tenuous, lightly-sculptured types. These ammonites are also found sparingly with many of the robustly ornamented quadrate-whorled specimens (group 4b) such as the acanthoceratids, mammitids, prionocyclids, and in the Washita pyrite faunas; but they are rarely associated with the desmoceratids of the lower Duck Creek limestones.

The various types of uncoiled ammonoids of the Texas Cretaceous show an overwhelming preference for association with the ammonites characterized by robust sculpture and quadrate whorl sections (group 4) and the other faunas with which these occur. They are found, however, with the smooth ovate type (group 3). Where the tenuous (groups 5 and 6) ammonites occur to the approximate exclusion of other types as in the Glen Rose, Fredericksburg and Escondido the uncoiled cephalopods do not occur or are found rarely.

The pyrite faunal zones of the Washita present extremely complex assemblages and probably involve special ecological problems.

It has been noted that ammonites do not occur with rudistids, abundant reef-forming corals, or with *Orbitolina*, and that in a general way the possibility of finding ammonites tends to decrease with the abundance of large, thick-shelled, gastropods and pelecypods, and echinoids.

Nautiloids are not numerous or varied in the Texas Cretaceous, but they are found sparingly in all groups of strata with the possible exception of the Eagle Ford. With the single exception of the tenuous *Vorticoceras* of the Glen Rose all species have the general shell form of the modern *Nautilus*.

Types of sediments in which cephalopods are most likely to occur, and their paleoecological significance.—Although Texas Cretaceous cephalopods occur in a great variety of sediments, they are by no means present in all. It would appear that they definitely avoided waters where certain types of deposits were accumulating and favored others.

In the Texas Cretaceous, ammonites and nautiloids are rare or absent in the purer marine sands and sandstones such as the Trinity and Pauluxy where other marine fossils are found. They occur, however, in arenaceous limestones and shales in the Travis Peak, Glen Rose, Eagle Ford and Nacatoch, but are limited almost entirely to the sculptured forms with quadrate whorls (group 4) and to the tenuous types (groups 5 and 6). The obese, smooth forms (groups 1 and 2) and the smooth forms with ovate whorl sections (group 3) are not found in these arenaceous sediments, and the uncoiled forms such as *Hamites*, *Baculites*, *Scaphites* (group 7) are rarely found. In all probability the purer sands accumulated in waters that were too shallow, or too brackish, or where temperatures changed too rapidly for the well-being of the ammonites. Incidentally, these facts do not argue in favor of the oft-expressed idea that the empty shells of dead ammonites probably floated widely through the waters of the seas.

In the Texas Cretaceous ammonites have not been found in sediments of any kind that bear sun cracks, tracks of land (Dinosaurs) animals, littoral fossils, or fine ripple marks, although certain types are found in the broadly rippled beds of the Fredericksburg. The remains of other truly marine invertebrates may be abundant in such sediments as, for example, in much of the Glen Rose.

As already mentioned, ammonites are not found in reef limestones and *Orbitolina* beds. They are seldom found in shell beds or coquina limestones, but there are notable exceptions. For example, *Dufrenoya* is found in great abundance in an arenaceous, coquina-like limestone of the Travis Peak, and *Oxytropidoceras* and *Engonoceras* are often incorporated in the *Gryphaea* and *Exogyra* beds of the Goodland. Most types of ammonites appear to have fared poorly under the shallow and rapidly changing conditions where such sediments were accumulating.

Many black shales such as certain black,

fissile shale beds of the Eagle Ford, Navarro and other formations seem to have accumulated in an environment unfavorable to ammonites and nautiloids. Indeed, fossils of all kinds are rare in these black shales. This type of environment has been discussed at length by W. H. Twenhofel (1939). He emphasizes the significance of poor circulation and low oxygen content in the bottom waters of such an environment. It would appear, however, that the cephalopods which have been postulated as floaters and nectonic swimmers should be found in the black shales of this environment, but such is not the case.

The most numerous specimens and the greatest varieties of ammonites in the Texas Cretaceous are found in the marls, marly shales and marly limestones such as the Washita marly limestones, the Glen Rose marly shales of West Texas and the calcareous or marly shales of the Eagle Ford. Ammonites are often abundant in the crystalline, chalky and nodular limestone strata such as those found in the Fredericksburg, Austin chalk, and some Washita strata, but usually the variety under such conditions is not great. The smooth, obese forms with ovate whorl-sections (group 3) are limited almost entirely to the marls, and marly limestones.

Ripple marks are frequently observed features in the Texas Cretaceous rocks and since the size and other characteristics of these structures are an indication of the depth at which they were formed they are of some interest here (Bucher, 1917, 1919). Small to medium-sized current and wave ripple marks are abundant in some Glen Rose beds and at many other levels. They were evidently formed at quite shallow depths. The writer has found no ammonites or nautiloids associated with such structures. In other Glen Rose strata and at several levels in the Fredericksburg large ripples are widely developed. Many of the ripples are four to six inches in height and are as much as five feet from crest to crest (Scott, 1930). Often the ripples are made of *Gryphaea*, *Exogyra* and other oyster shells. The tenuous ammonites (groups 5 and 6) are occasionally found incorporated in the ripples. These ripples could scarcely have been formed at depths greater than 10–15 fathoms.

Fossil cephalopod habitats and their observed relationship to paleogeography.—From a geographic point of view the ancient seas which ammonites might conceivably have inhabited may be roughly classified into three groups: (1) the open seas of oceanic depth, (2) the geosynclinal seas of the great down-warped depressions often of considerable depth, (3) the usually shallow and extensive epeiric seas covering relatively stable epicontinental areas. The seas of oceanic proportions are of no concern here since little is known of their sediments or of the fossils they might have entombed. The known ammonites lived at various depths and under various other conditions imposed by the seas of the geosynclines and of the epicontinental areas. Furthermore, the conditions of life imposed by latitude characterizing the various seas as boreal, austral, equatorial, etc., are well recognized.

Early students of Mesozoic ammonites in Europe, notably Neumayr, observed the sporadic occurrence of the smooth, obese types of ammonites such as *Phylloceras* and *Lytoceras* and offered the explanation that these genera were equatorial and sub-equatorial in distribution. This is possibly a partial explanation of why they are not found extensively in the northern regions of Europe, but their occurrence in equatorial and subequatorial Mesozoic deposits is far from general.

Students of the Jurassic and Cretaceous in the Alps and other Mediterranean countries, particularly Kilian and Haug, have shown that *Phylloceras* and *Lytoceras* and other smooth, obese ammonites (groups 1 and 2) do not occur in littoral or neritic deposits, but that *they are the predominant element of the fauna only in the axial regions of the geosynclines and in the deepest or bathyal parts of such basins* (Haug, 1920, p. 938). Here they are often more numerous than all of the other macrofauna combined. The sediments in which they are found are essentially marls. Large, thick-shelled pelecypods and gastropods, corals, bryozoans, oysters and the tenuous and uncoiled types of cephalopods are wanting or extremely rare. The lightly sculptured ammonites with quadrate whorl-sections (group 4a) and the smooth obese forms with ovate whorl-sections (group 3) are present but are greatly

subordinate in numbers. More often than not the cephalopods of such deposits are preserved as pyrite pseudomorphs.

Surrounding these bathyal areas according to Kilian and Haug, there is always a neritic zone in which other ammonoids often occur in great profusion to the complete or almost complete exclusion of the smooth, obese forms. With the neritic ammonites are the usual varieties of other faunas including medium-sized gastropods, pelecypods and limited numbers of echinoids. Finally, around this zone the reef and near-shore littoral deposits do not yield ammonites. The fossils of reef building animals, and large and thick-shelled gastropods and pelecypods are numerous.

In the Alpine area of southern Europe the bathyal, geosynclinal seas of the Mesozoic were particularly well developed while the neritic and littoral zones surrounding them were extremely narrow. In Texas the opposite is the case. Here the only geosynclinal area of significance during the Cretaceous was in Trans-Pecos during Travis Peak and Glen Rose time. Its axis corresponded in a general way to the Quitman Mountains. This area was, in reality, only the shallowed northern extension of one of the great Mexican geosynclines, and does not appear to have been deep enough in Texas to be attractive to *Phylloceras* and *Lytoceras* (groups 1 and 2). These, however, are found in the deeper parts of the basin in Mexico (Böse, 1923; Burckhardt, 1930).

On the other hand, the neritic seas of Texas achieved an areal development which on account of the limitations of space would have been impossible in Europe, and it is possible to subdivide the varied deposits left by them into infraneritic, epineritic,

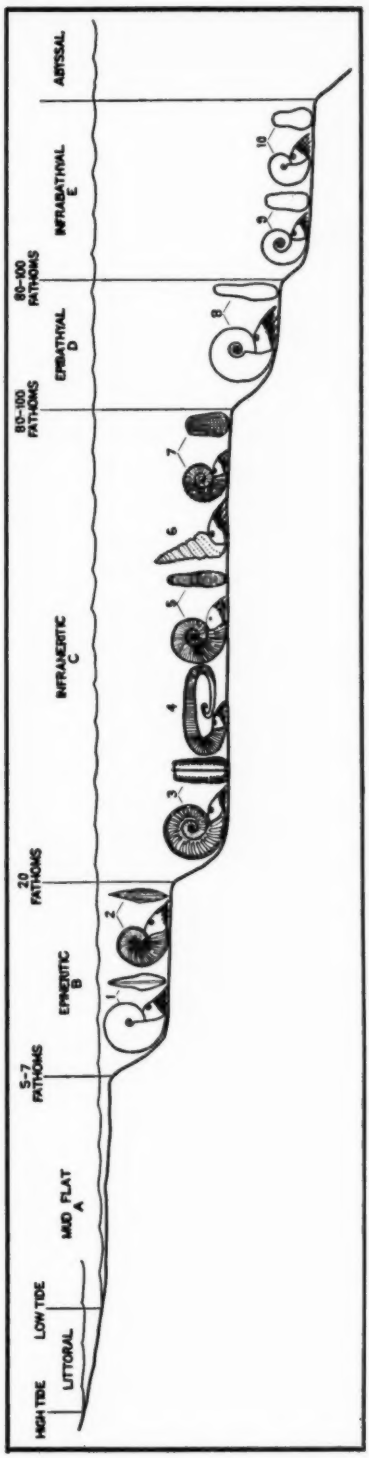

Fig. 8.—Diagram suggesting the necto-benthonic habitat and bathymetric distribution of the principal types of Texas Cretaceous ammonoids as illustrated in the Texas area. The drawing is not to scale and the terraced arrangement is used to better emphasize the groupings. There are, of course, numerous gradations from one zone to the other.

1. *Engonoceras*, 2. *Oxytropidoceras*, 3. *Mortoniceras*, 4. *Hamites*, 5. *Hypacanthoplites*, 6. *Turrilites*, 7. *Douvilleiceras*, 8. *Desmoceras*, 9. *Lytoceras*, 10. *Phylloceras* (*Lytoceras* and *Phylloceras* and related genera are not found in Texas).

reef, and mud flat zones, all well developed at various levels and lying in order between the bathyal (epibathyal) and littoral zones. Because of the flatness of many of the shore areas the littoral deposits are also widely developed.

In the narrow, neritic areas of Europe the tenuous types of ammonites did not attain any considerable development, and such

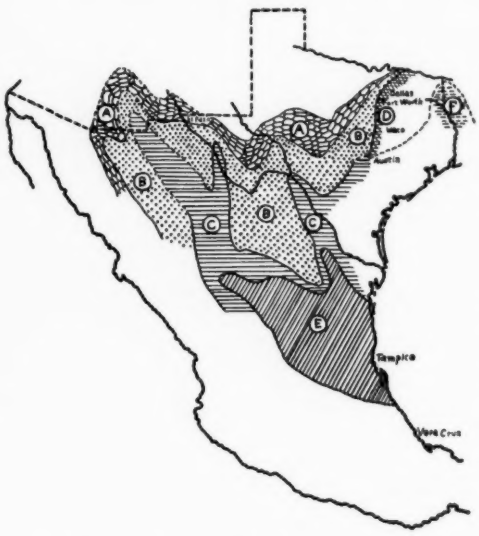

FIG. 9.—Sketch showing the distribution of the principal bathymetric zones of about Albian (Trinity, Fredericksburg, Washita) time in the Texas-Mexican area.

A. Mud flat and associated deposits of Trinity age, *B*. Epineritic (often zoogene) deposits, *C*. Infraneritic deposits of Glen Rose and Fredericksburg age, *D*. Epibathyal (lower Washita) and infraneritic (middle and upper Washita) overlapping epineritic deposits of North Texas, *E*. Infrabathyal and epibathyal deposits of the geosynclinal regions of Central Mexico, *F*. Infraneritic subsurface deposits of Trinity age in Louisiana and East Texas.

genera as *Engonoceras*, *Knemiceras* and *Oxytropidoceras* are rare. In the shallow and abnormally extensive epeiric seas covering Texas, particularly during Glen Rose and Fredericksburg time, these types of ammonites (groups 5 and 6) found a set of living conditions to their liking. They swarmed the seas in enormous numbers and evolved into numerous genera and species.

Lying shoreward from, and surrounding the epineritic area, are the extensive reef limestones and the mud flat limestones and shales containing sun cracks, animal tracks, dinosaur bones, rain prints and incredible numbers of *Orbitolina*, large thick-shelled pelecypods, gastropods, echinoids and other marine fossils. In both these types of sediments and in the bordering littoral deposits ammonites and nautiloids of all kinds are rare or absent.

The paleogeographic map, supplemented by other data (fig. 9) shows, in broad outlines, the bathymetric zones of the Mexican and Texan Aptian and Albian seas as indicated by the different types of cephalopods. Figure 8 illustrates the writer's conception of the bathymetric distribution of the principal types of ammonoids of the Texas Cretaceous area.

Inferred and possible paleoecological effects of the water medium, such as depth, salinity, temperature, light, waves, currents, oxygen content, and bottom upon ammonite life.—It has been observed that ammonoids normally are not found in deposits that were deposited very near the shore, and that different types are found at varying distances from the old shore. It has, also, been noted that certain types of ammonoids favored the very shallow waters, whereas others sought considerable depths. It is doubtful, however, if either of these factors was, within itself, of great importance to the ammonites. The only factor which varies directly with depth is pressure, and it is possible that variations in pressure which the ammonoids encountered affected their distribution. Temperature and light vary with depth, but they are also dependent on other factors. Waves are phenomena of the surface or near surface. Regardless of whether the influence of depth was direct or indirect, there can be no question that, other factors being equal, various types of Cretaceous ammonoids were pretty well distributed in bathymetric zones.

It has been pointed out that modern cephalopods are extremely sensitive to reduced salinity and there is good reason to believe that the ancient ammonoids reacted similarly in this respect. Glen Rose seas appear to have been less than twenty fathoms deep over extensive areas, as shown by the widespread echinoids, oyster beds, and

the fossils of reef building animals. It is probable that the strata filled with the large thick-shelled gastropods such as *Natica* and *Tylostoma* were deposited at depths of seven or eight fathoms. The extensively rippled beds, the coquina limestones and beds filled with borings of clams and worms must have approached the water surface (mud flat). Strata marked by sun cracks and land animal tracks were actually exposed, at times, to the atmosphere. It is conceivable that the Texas area could have been occasionally subjected to violent rain storms amounting to several inches. Far from shore in the shallow seas, even where depths attained ten or more fathoms, such rains would have reduced the water salinity to the danger point for the ammonoids. Around the edges of such seas and for considerable distances from the shore great reduction of salinity would have resulted from the influx of fresh water from the lands. Possibly these conditions offer one explanation of why cephalopod fossils are not found in Glen Rose sediments over wide areas in the Texas region. It is also possible that during extended droughts evaporation under a tropical sun could have greatly increased the salinity of the shallow water. This, however, probably did not influence cephalopod life except where evaporation was carried to excess.

It is a well known fact that cephalopod larvae and eggs are extremely intolerant of high temperatures. The heat of a modern Texas summer would easily raise the temperature of a broad body of water, with a depth of 1–10 fathoms, above the tolerance of modern cephalopod young.

In this fact may lie an additional explanation of the absence of ammonoids over much of the area occupied by the abnormally shallow expanses of the Texas Glen Rose Seas. Temperature might also have been a limiting factor in the distribution of the various other types of cephalopods. Pompeckj (1898), Haug (1900) and Kilian (1903) attributed the sporadic occurrence of *Lytoceras* and *Phylloceras* to favorable bathymetric conditions. Haug used the term "stenothermic" for those smooth obese types with circular whorl sections (groups 1, 2) living in the relatively even temperatures of the deep bathyal regions. For the forms dwelling in relatively shallow water and consequently capable of enduring considerable variations of temperature, he used the term "eurythermic."

Whether or not these terms are justifiable to the extent that Haug has used them is difficult to determine. There can be little doubt, however, that some factor associated with depth has influenced the uneven distribution of the different types of ammonoids as outlined in the early pages of this paper.

In defining the neritic zone its lower limit was placed at the lower limit of abundance of photosynthetic plants. This level is directly dependent upon the depth of sunlight penetration, and for most marine waters appears to be about 80 to 100 fathoms. It may be shallower in areas where the water is turbid and in high latitudes, or a little deeper in tropical and clear waters (Hesse, Richards and Allee, 1937). Because of its effect on growing plants, light has a tremendous influence, either directly or indirectly, on all living things. The marine plants do not appear to have served the ammonoids directly as food, and yet only the obese, smooth forms (groups 1, 2, 3) are found in any abundance in deposits formed below the level of abundant plant growth. It appears not improbable that the plants influenced ammonite distribution. The present depth distribution of most shelled gastropods is almost entirely limited to the extent of these "submarine prairies of algae" on which they graze. The lower limit of abundant sculptured ammonites appears to be at about the lower limit of these green plants, that is, at the 80–100 fathom line. Possibly the plants were attractive to the food animals upon which the ammonites were dependent; or perhaps the ammonites used the plants for concealment and protection against their enemies.

It appears that most ammonoids and nautiloids of the Texas Cretaceous seas avoided all areas where wave and current action assumed any considerable violence. This is indicated by the fact that ammonites are not found in reef deposits; only certain types (groups 5, 6) are found associated with ripple marks and then only with the very large ones. It has been pointed out that *Oxytropidoceras* (tenuous, sculptured, group 5) and *Engonoceras* (tenuous, smooth,

group 6) occur in broadly rippled strata of the Walnut and Goodland. These fall under the general heading of "large" or para-ripples as classified by Bucher (1919). That author emphasized the fact that assembled data on ripple marks is far from adequate for determinations of depth, velocity of currents, magnitude of waves and effects on particles of varying sizes. Bucher believes that the very large para-ripples in which coarse and fine materials are evenly distributed are formed by currents set up in shallow open seas by tides and storms such as tropical hurricanes. He suggests that they could not have developed in depths in excess of 25 meters (12 fathoms). These structures occur in several levels in the Glen Rose and Fredericksburg, and are widespread, having been observed over an area as much as 50 miles wide and 200 miles in length. Other facts agree with conclusions drawn from a study of the ripple marks that these seas were shallow (perhaps less than 12 fathoms), open to the seas and subject to tidal variations and currents; and were, at least periodically, disturbed by violent storms, possibly tropical hurricanes. Most of the time the water must have been clear as indicated by the calcareous sediments but, when violently disturbed so that the relatively large *Gryphaea* shells were whipped into ripples, the finer particles of the bottom must have become suspended, greatly increasing the turbidity of the shallow waters. Apparently, only *Oxytropidoceras* and *Engonoceras* and related forms among the shelled Cephalopoda were able to survive such conditions in any considerable numbers.

Some kind of Cretaceous ammonoid seems to have been capable of occupying almost any kind of bottom. They, however, probably preferred bottoms of calcareous mud and ooze. Specimens are seldom found in the purer types of sand, but their absence from such deposits should probably be sought in factors other than bottom conditions.

The so-called "black shale environment" was probably unfavorable in extreme cases for ammonoids, but in reality the ammonoids seem to have been able to endure such bottom conditions better than most mollusks. Many black shales are filled with ammonoids, although the strongly carbonaceous and bituminous shales as a rule are barren of all fossils.

It is possible that bottom effect on the cephalopods was more indirect than direct. The absence of these animals and their food in seas with extremely foul bottoms is easily explained by the absence of oxygen in such stagnant conditions. On the other hand it is apparent that ammonoids did not have oxygen requirements comparable to the reef-forming animals. Incidentally, these facts of distribution of the ammonoids appear to the writer to present the most serious objection to the idea that certain types of ammonoids were planktonic, or that they swam about widely near the surface. If such had been the case, such types as *Macroscaphites*, which has been listed as a floater, should be found indiscriminately in bituminous and carbonaceous deposits and in reef sediments.

The theory that ammonoids floated widely over the oceans after the death of the animal (because of gas accumulation in the chambers) suffers similarly in the light of these facts.

SUMMARY AND CONCLUSIONS

In a problem of this kind the paleoecologist is greatly handicapped by the fact that every criterion available is susceptible of a variety of interpretations. In this paper an effort has been made to consider the pertinent data at hand and then arrive at an interpretation as near as possible in conformity with all the facts. The following general conclusions appear to be justified.

1. From the data presented the conclusion that most ammonites of the Texas Cretaceous occupied a necto-benthonic habitat seems inescapable. There is some evidence, drawn from a study of shell morphology, that certain types such as the partially uncoiled and hooked *Macroscaphites* and similar forms lived a floating existence. Aside from the fact, however, that shelled animals, other than Foraminifera, do not usually float, all other factors argue against such a mode of life. Some ammonoid species appear to have been quite good swimmers, but the conclusion that they enjoyed a nectonic existence[7] swimming widely through the

[7] Douville, H. (1911), arrived at the conclusion that the thin, lightly ornamented types were nectonic swimmers.

seas is not indicated on account of the limited bathymetric and geographic distribution of such types. It is probable that most or all of the Texas Cretaceous ammonoids could swim, but some, such as the tenuous, smooth or lightly sculptured forms (groups 5 and 6) and the straight (group 7a) or strongly recurved types must have been fairly good swimmers. Most, and probably all, species crawled a great deal on the bottom, darted quickly backward from place to place by swimming, or swam in a hovering position just above the bottom as they sought their prey, consisting probably of Crustacea, small fishes, etc. Being capable of at least limited vision, they could stalk their prey or hover in the soft sediments or among the bottom plants and animals at the approach of their enemies.

2. Little is known concerning the eggs and their early developmental stages, even in the living cephalopods, and this is particularly true of *Nautilus*.

3. The young of the ammonoids were probably very similar to the adults except for size. With adulthood, however, they became sexually mature; many species apparently developed restricted apertures to the shell, prolonged rostrae as a continuation of the ventral shell wall, or a so-called "hyponomic sinus." Others developed uncoiled, hooked and recurved shells or became spirally and irregularly coiled. Modern biologists would explain these modifications in terms of adaptations. What the purpose of these adaptations may have been is not apparent.

4. The Texas Cretaceous ammonoids are pretty definitely distributed according to bathymetric zones as follows:

(1) The littoral sediments deposited on the shore between tide levels, and sediments deposited in estuaries and other brackish water areas do not carry ammonites probably because these cephalopods could not tolerate extremes of temperature, turbulent waters, or reductions in water salinity of any considerable degree.

(2) Seaward from the littoral zone were the shallow Cretaceous seas which approached the low-lying flat lands as extremely shallow bodies of water the sediments of which may be termed mud (sometimes calcareous, sometimes carbonaceous) flats. These solidified muds are characterized by numerous small and medium sized ripple marks, sun cracks, and the tracks of land and subaquatic animals. It is probable that violent rains greatly reduced the salinity of these seas, but did not make the water brackish, while periods of drought, sunshine and wind increased the salt concentration. The temperature range of the water was probably considerable. The sediments of this bathymetric zone are termed mud flat deposits. It is believed they were deposited, for the most part, at depths of less than 5 to 7 fathoms. Ammonites are not found or are so rare as to amount to accidental finds. Large, thick-shelled pelecypods and gastropods, oysters, worm tubes, bryozoans, and *Orbitolina* may be abundant. See zone A on chart figure 8 and on map figure 9.

(3) Closely related to the mud flat seas from the standpoint of ammonoid habitation were the areas of reef-building animals, sometimes referred to as the *zoogene* facies. Ammonites are not found in the deposits of such seas, probably because the water was too rough and subject to too great variations of temperature and salinity.

(4) Lying adjacent to, and seaward from, the mud flat and zoogene zones are the sediments of the epineritic zone. This bathymetric zone was particularly well represented in Texas by the broad, shallow Cretaceous seas. The sediments of this zone carry myriads of echinoids, large pelecypods and gastropods with thick shells, *Gryphaea*, *Exogyra* and other oyster beds, corals, and crustacean fragments. Evidences of plant growth are abundant. The ammonoids are of the tenuous types such as *Oxytropidoceras*, *Knemiceras*, *Engonoceras*, *Placenticeras* (groups 5, 6). Other types of ammonites are rare or absent.

Some of the sediments are characterized at intervals by the large para-ripples, probably formed by storms (such as tropical hurricanes) and tides. It is believed these sediments of the epineritic zone were deposited at depths ranging from 7 or 8 to 20 fathoms. This bathymetric zone is best represented in the Fredericksburg. It is also developed at certain levels in the Glen Rose, Taylor, Navarro and equivalent beds. The position of the epineritic sediments of the

Texas Cretaceous seas is illustrated by zone B on the chart figure 8 and the map figure 9.

(5) The infraneritic zone lies between depths of about 20 and 80–100 fathoms. The fauna of this bathymetric zone is rich and varied. The ammonites consist of the great hosts of sculptured, and uncoiled and abnormally coiled types (groups 4, 7). The tenuous types of ammonoids are rare or absent. Gastropods, pelecypods, are numerous and varied, and echinoids are found. Evidences of plant growth are abundant. The pelecypods and gastropods, however, are not of the large, thick-shelled species. Members of the oyster family are relatively rare. Corals and rudistids are not found. This bathymetric zone or facies is represented in Texas by the Glen Rose (in part) of the Quitman Mountain area, by the Washita of North Texas (except the Duck Creek limestone). The Eagle Ford, Austin chalk and certain areas of the Taylor probably fall into this grouping.

The distribution of infraneritic species of the Texas Albian is illustrated by zone C on the chart figure 8 and by zones C and F on the map figure 9.

(6) The epibathyal zone. Smooth ammonoids with ovate to sub-quadrate whorl sections, such as *Desmoceras*, *Uhligella*, *Puzosia*, lived in a shallower bathyal zone which is designated the epibathyal zone, at or near the 100 fathom line. The absence of algal remains and the scarcity of gastropods suggests that green plants were not abundant. Ammonoids make up the principal element of the fauna. A few of the sculptured forms (group 4) and certain uncoiled types are found associated with them. The lower Duck Creek limestone represents the only level in Texas where the fauna of this bathymetric zone is at all developed, and then only for an extremely brief time. The position of this facies is suggested by the zone D of the chart, figure 8, and the map figure 9. The facies also constitutes a large part of zone E of East Central Mexico as shown on the map and possibly other regions.

(7) The infrabathyal zone. The absence in Texas of such obese, smooth genera as *Lytoceras*, *Phylloceras*, *Tetragonites*, *Gaudryceras*, *Kossmattella*, *Jaubertella*, *Silesites* (groups 1, 2) is explained on the basis that the Texas Cretaceous seas were not sufficiently deep to provide the type of living conditions adapted to their well being. Such ammonoids appear to have lived below the 100 fathom line, where light was not sufficiently strong to support green plants. These types also existed far from land in the very centers of great geosynclinal basins. Few other fossils are associated with them. The position of the infrabathyal zone is illustrated by zone E of the chart, figure 8, and of the map, figure 9 (in part).

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A MIOCENE MICROFAUNA OF HAITI

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ABSTRACT—The foraminiferal fauna of the upper middle Miocene of Haiti at Port-au-Prince has been classified into 15 families, 53 genera and 111 species. Twenty species and one variety are considered new. The local name of Port-au-Prince has been introduced for these beds and their correlation with the Bowden marl of Jamaica suggested.

ACCORDING to the studies of Woodring and of Schuchert the Miocene of Haiti may be classified as follows:

Upper Miocene —Absent
Middle Miocene—Beds near Port-au-Prince
—Beds along south side Cul-de-Sac Plain
Lower Miocene —Artibonite group
Las Cahobas
Thomonde and Maissade
Madame Joe

Collections were made from the upper bed of the middle Miocene by the junior author in order to make known a beautifully preserved prolific foraminiferal fauna that supports the belief that the Miocene beds at Port-au-Prince are closely related to the Bowden Marl of Jamaica and other upper middle Miocene beds of the Caribbean region. The Haitian deposits consist of rather unconsolidated, bluish-gray marl and fine-grained sands interbedded with layers of yellowish limestones. With its abundant *Globigerina*, *Globorotalia*, *Nodosaria* and *Planulina* this succession seems to have been deposited in deeper water than the Bowden Marl. Because of distinctive environmental and faunal characters of the Haitian deposits we believe that the introduction of the local name of Port-au-Prince for the marly fossiliferous deposits of the upper middle Miocene would be a decided advantage in tabulating the faunal occurrences.

SYSTEMATIC DESCRIPTIONS

Family MILIOLIDAE d'Orbigny, 1839
Genus PYRGO Defrance, 1824
PYRGO MURRHINA (Schwager)
Plate 43, figure 9

Biloculina murrhina SCHWAGER, *1866*, Novara-Reise, geol. Theil, vol. 2, p. 203, pl. 4, figs. 15a–c.

Pyrgo murrhina CUSHMAN, *1929*, U. S. Nat. Mus. Bull. 104, pt. 6, p. 71, pl. 19, figs. 6, 7; CUSHMAN and JARVIS, *1930*, Jour. Paleontology, vol. 4, no. 4, p. 357, pl. 32, figs. 7a–b.

A worn Haitian specimen seems referable to this species. The part of the keel opposite the aperture is not excavated. *Pyrgo murrhina* is reported to range from Miocene to the present. Dimension of figured specimen, length, 0.6 mm.

Genus SIGMOILINA Schlumberger, 1887
SIGMOILINA CELATA SCHLUMBERGERI (Silvestri)

Sigmoilina schlumbergeri SILVESTRI, *1904*, Pont. accad. Nuovi Lincei Mem., vol. 22, p. 267.
Sigmoilina celata schlumbergeri CUSHMAN, *1929*, U. S. Nat. Mus. Bull. 104, pt. 6, p. 49, pl. 11, figs. 1–3.

Several representatives of this species are in the Haitian collections.

Family TEXTULARIIDAE d'Orbigny, 1846
Genus TEXTULARIA Defrance, 1824
TEXTULARIA LYTHOSTROTUM (Schwager)
Plate 41, figure 3

Plecanium lythostrotum SCHWAGER, *1866*, Novara-Reise, geol. Theil, vol. 2, p. 194, pl. 4, figs. 4a–c.

Test short, almost as broad as high; in edge view subcuneate and becoming almost half as thick as wide; apertural end a curved plane normal to axis of the test, the edges squarely truncate; chambers comparatively few, about six pairs, the sutures oblique and slightly curved, the earlier ones apparently forming a more acute angle with axis of test; sutures very indistinct; surface arenaceous, rather coarsely so, in relation to size of the test; aperture in a small re-entrant. Length of larger specimen, 0.83 mm.; breadth, 0.70 mm.; thickness, 0.41 mm.

TEXTULARIA WARRENITES
Coryell and Rivero, n. sp.
Plate 41, figure 4

The test is marked by a longitudinal ridge formed by a thickening of the chambers; end view subrhomboidal; peripheral view cuneate; sutures moderately oblique, and indistinct; surface rather roughly arenaceous.

This species has some resemblance to *T. warreni* Cushman and Ellisor, especially to the specimen figured by Cushman and Ponton in the Florida Geol. Survey Bull. 4, except that *T. warreni* has raised sutures, generally more roughly arenaceous and more rapidly expanding test than *T. warrenites*. Length, 0.95 mm.

Genus TEXTULARIELLA Cushman, 1927
TEXTULARIELLA BARRETTII
(Jones and Parker)

Textularia barrettii JONES and PARKER, *1863*, British Assoc. Rept., Newcastle Meeting, pp. 80, 105; *1876*, Annals Soc. Mal. Belg., vol. 11, p. 99 (Woodcut).
Textulariella barrettii CUSHMAN, *1937*, Cushman Lab. Foram. Research, Spec. Pub. no. 8, p. 66, pl. 7, figs. 5–8.

This species is represented by two specimens in our collection. The Haitian forms are somewhat smaller than those from the Bowden marl of Jamaica. It occurs also in the Upper Eocene, Cooper marl of South Carolina, Miocene of Santo Domingo and of Venezuela, and in the recent deposits off the coast of Florida. Length of the larger specimen, 0.75 mm., thickness 0.64 mm.

Genus VULVULINA d'Orbigny, 1826
VULVULINA SPINOSA MIOCENICA Cushman
Plate 41, figure 1

Vululina spinosa miocenica CUSHMAN, J. A., *1932*, Cushman Lab. Foram. Research Contr., vol. 8, pt. 4, p. 80, pl. 10, fig. 10.

The Haitian specimen has proportions similar to Cushman's variety not withstanding its somewhat worn conditions which make the margins less spinose and the sutures in the later biserial stage less prominent. Length of figured specimen, 1.20 mm.; width 0.60 mm.

Family ATAXOPHRAGMIIDAE
Schwager, 1877
Genus DOROTHIA Plummer, 1931
DOROTHIA CARIBAEA Cushman
Plate 41, figure 5

Dorothia caribaea CUSHMAN, *1936*, Cushman Lab. Foram. Research, Spec. Pub. no. 6, p. 31, pl. 5, figs. 3a–c; —, *1937*, Ibid., no. 8, p. 99, pl. 11, figs. 5a–b.

This species is represented by a specimen with a length of 1.40 mm., breadth of 0.90 mm., and thickness of 0.74 mm. It also occurs off Cape Cruz, Cuba, in 305 fathoms of water.

DOROTHIA CALIFORNICA
Cushman and Kleinpell
Plate 43, figures 2a–b

Dorothia californica CUSHMAN and KLEINPELL, *1934*, Cushman Lab. Foram. Research Contr., vol. 10, p. 1, pl. 1, figs. 18a–b; CUSHMAN, *1937*, —, spec. pub., no. 8, p. 93, pl. 10, figs. 6a–b.

The Haitian specimen is apparently somewhat distorted, making the sutures slightly oblique instead of horizontal as in the type of *D. californica*. Length, 0.65 mm.; thickness, 0.3 mm.

Genus GAUDRYINA d'Orbigny, 1939
GAUDRYINA (PSEUDOGAUDRYINA)
ATLANTICA (Bailey)
Plate 41, figure 2

Textularia atlantica BAILEY, *1851*, Smithsonian Contr., vol. 2, art. 3, p. 12, pl. 10, figs. 38–43.
Gaudryina atlantica CUSHMAN, *1922*, U. S. Nat. Mus. Bull. 104, pt. 3, p. 70, pl. 13, figs. 1–3.
Gaudryina (Pseudogaudryina) atlantica CUSHMAN, *1937*, Cushman Lab. Foram. Research, Spec. Pub. no. 7, p. 95, pl. 14, figs. 4, 5.

A worn specimen with the edges considerably rounded by weathering and with the sutures and aperture somewhat obscured has been referred to this species. It is also reported as occurring in the recent deposits off the northeastern coast of United States; in the Miocene of Bluff Bay, Jamaica, of the State of Falcon, Venezuela, and of Trinidad. Length, 1.35 mm.; width, 0.70 mm.

Genus PSEUDOCLAVULINA
Cushman, 1936
PSEUDOCLAVULINA MEXICANA (Cushman)
Plate 43, figure 4

Clavulina humilis mexicana CUSHMAN, *1922*, U. S. Nat. Mus. Bull. 104, pt. 3, p. 83, pl. 16, figs. 1–3.

Pseudoclavulina mexicana CUSHMAN, *1937*, Cushman Lab. Foram. Research Spec. Pub. no. 7, p. 117, pl. 16, figs. 5–11.

Due to poor preservation the earliest chambers are indistinct; the subsequent triserial chambers forming the triangular portion of the test is followed by two subglobular uniserial chambers. The aperture has a slight neck and is apparently crescentic. The fossil specimens seem to be much less roughened with sponge spicules than the recent forms.

This specimen appears to be a young form of Cushman's species. It is somewhat smaller than the average. Representatives of this species have been reported from the recent sediments of the West Indies; in the Miocene of the Dominican Republic, near Buff Bay, Jamaica and in Trinidad; in the Tremblor formation of California. Length, 0.92 mm.; thickness, 0.35 mm.

Family VALVULINIDAE Cushman, 1933
Genus EGGERELLA Cushman, 1933
EGGERELLA BRADYI (Cushman)

Verneuilina pygmaea H. B. BRADY, *1884*, Challenger Rept., Zool., vol. 9, p. 385, pl. 47, figs. 4–7 (not *Bulimina pygmaea* Egger).
Verneuilina bradyi CUSHMAN, *1911*, U. S. Nat. Mus. Bull. 71, pt. 2, p. 54, text figs. 87a–b.
Eggerella bradyi CUSHMAN, *1937*, Cushman Lab. Foram. Research, Spec. Pub. no. 8, p. 52, pl. 5, fig. 19.

This species is represented in the Haitian collection by two small specimens. It also occurs in the Miocene of Trinidad. Length of larger specimen, 0.55 mm.; width, 0.48 mm.

Genus KARRERIELLA Cushman, 1933
KARRERIELLA BRADYI (Cushman)
Plate 43, figure 5

Gaudryina pupoides H. B. BRADY, *1884* (not d'Orbigny), Challenger Rept., Zool., vol. 9, p. 378, pl. 46, figs. 1–4.
Gaudryina bradyi CUSHMAN, *1911*, U. S. Nat. Mus. Bull. 71, p. 67, text figs. 107a–c.
Karreriella bradyi CUSHMAN, *1937*, Cushman Lab. Foram. Research, Spec. Pub. no. 8, p. 135, pl. 16, figs. 6–11.

This species is moderately common in Haiti. It has also been identified as occurring in the Miocene of Ecuador, Pliocene of New Guinea and Southern Spain and widely distributed in the recent oceans in fairly deep water. Dimensions of figured specimen: length, 0.8 mm.; width, 0.44 mm.

KARRERIELLA SUBCYLINDRICA (Nuttall)
Plate 43, figures 1a, b

Gaudryina subcylindrica NUTTALL, *1928*, Geol. Soc. London Quart. Jour., vol. 84, p. 76, pl. 3, figs. 17, 18.
Karreriella subcylindrica CUSHMAN, *1937*, Cushman Lab. Foram. Research, Spec. Pub. no. 8, p. 132, pl. 15, figs. 25a, b.

Mature and apparently immature specimens occur in the Haitian collection. The biserial portion shows more variability when compared with the morphotypes than with the type figures. Length of specimen figured, 1.60 mm.

Genus LISTERELLA Cushman, 1933
LISTERELLA NODULOSA (Cushman)

Plate 41, figure 7; plate 43, figures 3a, b

Clavulina communis nodulosa CUSHMAN, *1922*, U. S. Nat. Mus. Bull. 104, pt. 3, p. 85, pl. 18, figs. 1–3.
Listerella nodulosa CUSHMAN, *1937*, Cushman Lab. Foram. Research, Spec. Pub. no. 8, pp. 26, 105, pl. 17, figs. 13–19; —, *1936*, Geol. Soc. America Bull., vol. 47, no. 3, p. 428, pl. 4, figs. 6a–b.

The Haitian specimens show mostly the early chambers, and thus omit some of the typical features for the species. This species is recorded also from the Miocene of Trinidad and of Buff Bay, Jamaica. Its most similar morphic species is *Listerella communis*, described only from Europe. Dimension of figured specimen, length, 1.14 mm.

Family NODOSARIIDAE Schultze, 1854
Genus DENTALINA d'Orbigny, 1839
DENTALINA PAUPERATA d'Orbigny
Plate 41, figures 20, 21

Dentalina pauperata D'ORBIGNY, *1846*, Foram. Foss. Bassin Tertiaire, Vienne, p. 46, pl. 1, fig. 57–58; GALLOWAY and MORREY, *1929*, Bull. Am. Paleontology, vol. 15, no. 55, p. 13, pl. 1, fig. 8; CUSHMAN, *1929*, Cushman Lab. Foram. Research Contr., vol. 5, pt. 4, p. 85, pl. 12, figs. 23, 24.

The Haitian specimens do not show the presence of an initial spine as shown in the figures of d'Orbigny, but they agree with some of the figured morphotypes. This species has been recorded from lower Oligocene of Europe, and the Miocene and other Tertiary beds of North and South America. Dimensions of figured specimens, length, 1.25 mm., and 1.3 mm.

DENTALINA SEMINUDA Reuss
Plate 42, figure 4

Dentalina seminuda REUSS, *1850*, Akad. Wiss. Wien, Math.-naturwiss. Kl., Denkschr., vol. 1, p. 367, pl. 46, fig. 9.

The two specimens assigned to this species from the Haitian collection appear as megalospheric representatives when compared with the figures of Reuss. The development of the costae over the early chambers is variable; in one they occur on the four early chambers and in the other only on two above the initial apical termination. Length of the figured specimen, 1.65 mm.

DENTALINA VERTEBRALIS (Batsch)
Plate 42, figures 1, 3

Nautilus (Orthoceras) vertebralis BATSCH, *1791*, Conch. Seesandes, p. 3, no. 6, pl. 2, figs. 6a–b.
Nodosaria vertebralis BRADY, *1884*, Challenger Rept., Zool., vol. 9, p. 514, pl. 63, fig. 35; pl. 64, figs. 11–14; CUSHMAN, *1919*, Carnegie Inst. Washington Pub. 291, p. 35, pl. 7, figs. 3–5; NUTTALL, *1928*, Geol. Soc. Quart. Jour., vol. 84, p. 64; GALLOWAY and MORREY, *1929*, Bull. Am. Paleontology, vol. 15, no. 55, p. 14, pl. 1, figs. 10a–b; CUSHMAN, *1929*, Cushman Lab. Foram. Research Contr., vol. 5, pt. 4, p. 86; CUSHMAN and JARVIS, *1930*, Jour. Paleontology, vol. 4, no. 4, p. 360.
Dentalina vertebralis CUSHMAN, *1931*, Cushman Lab. Foram. Research Contr., vol. 7, pt. 3, no. 110, p. 66, pl. 8, figs. 20, 21.

There are several specimens in our Haitian collection that vary somewhat in the number of costae, but are otherwise similar to the morphotypes of this species. Length of the figured specimen, 1.8 mm.

Genus FISSURINA Reuss, 1850
FISSURINA CRENULATA
Coryell and Rivero, n. sp.
Plate 41, figures 15a, b

Test rather large for the genus; in lateral view the specimen is subovoid, narrowing towards aperture, truncate at apertural end; in edge view, widest at middle, base broadly rounded, test narrowing rapidly towards aperture; in apertural view, broadly elliptical; base ornamented with a few irregular striae or wrinkles, which are barely visible in front view of test, more so in side view, as they extend up highest at the sides, that is, in the plane of the long diameter of the test; aperture a rather large slit.

Dimensions of test, height, 0.95 mm.; width, 0.75 mm.; thickness, 0.6 mm.

Genus FRONDICULARIA De France, 1826
FRONDICULARIA TENUISSIMA Hantken
Plate 41, figure 16

Frondicularia tenuissima HANTKEN, *1875*, A. magy. kir. földt. int. evkönyve, vol. 4, p. 36, pl. 13, fig. 11; —, *1875*, Ungar. geol. Anst. Jahrb., vol. 4, p. 43, pl. 13, fig. 11; CUSHMAN, *1927*, Cushman Lab. Foram. Research Contr., vol. 3, pt. 2, p. 111, pl. 22, fig. 11; NUTTALL, *1935*, Jour. Paleontology, vol. 9, no. 2, p. 125, pl. 14, fig. 21; CORYELL and EMBICH, *1937*, Jour. Paleontology, vol. 11, no. 4, p. 296, pl. 41, fig. 21.

The Haitian specimen shows some coiled chambers as recorded in the morphotypes of some of the figured microspheric forms. *F. tenuissima* has been reported from the Eocene of Venezuela, the upper Eocene and lower Oligocene of Mexico, upper Eocene of Panama, upper Eocene and lower Oligocene of Europe. The dimensions of the figured specimen, length, 0.95 mm.; width, 0.37 mm.

FRONDICULARIA BULBOSA
Coryell and Rivero, n. sp.
Plate 41, figure 18

A broken specimen with a large proloculum raised above the surface of test. The shape of the chambers is somewhat like *F. alata* d'Orbigny as figured by Cushman, but the test does not have the basal projections. Length, 1.2 mm.; width, 1.0 mm.

Genus LAGENA Walker and Boys, 1784
LAGENA ORBIGNYANA CARIBAEA Cushman
Plate 41, figure 22

Lagena orbignyana caribaea CUSHMAN, *1923*, U. S. Nat. Mus. Bull. 104, pt. 4, p. 41, pl. 7, figs. 6–9.
Fissurina orbignyana caribaea GALLOWAY and MORREY, *1929*, Bull. Am. Paleontology, vol. 15, no. 55, p. 22, pl. 2, fig. 17.

The inner keel of the Haitian specimen is somewhat less well developed than in the Ecuador form especially on the neck. The convexity of the former varies somewhat from the latter in being a little more gibbous aperturally. Length of specimen, 0.42 mm.

Genus LAGENONODOSARIA Silvestri, 1900

LAGENONODOSARIA EXTENSA
Coryell and Rivero, n. sp.
Plate 42, figure 12

In the Haitian assemblage of Foraminifera there occur a few fragmental nodosarian forms in which the adjacent spherical chambers are connected by a neck-like extension that is about $\frac{3}{4}$ as long and $\frac{1}{3}$ the thickness of the diameter of the chambers. This species is covered by longitudinal costae, more prominent and numerous on the chambers than on the necks. Length of the figured specimen, 1.4 mm.

LAGENONODOSARIA SIGMOIDEA
Coryell and Rivero, n. sp.
Plate 42, figure 9

A fragment of a lagenonodosarian form in which the length and thickness of the connecting neck is scarcely more than half the diameter of the spherical chambers has been assigned to this species. Some white spiral longitudinal costae ornament the specimens. The costal ridges become more numerous on the surface of the chambers by intercalations and disconnected alignments. Length of the figured specimen, 1.15 mm.

LAGENONODOSARIA SCHLICHTI (Reuss)
Plate 43, figure 8

Nodosaria schlichti REUSS, *1858*, Deutsche geol. Gesell. Zeitschr., vol. 10, heft. 4, art. 4, p. 435 (Nom. nud.); CUSHMAN, *1929*, Cushman Lab. Foram. Research Contr., vol. 5, pt. 4, p. 87, pl. 13, figs. 9, 10.

Only one chamber is present in this specimen with the remainder broken away, and the neck of the Haitian form is longer and thinner than former figured specimens. Length of the specimen, 0.53 mm.

LAGENONODOSARIA SPINICOSTA (d'Orbigny)
Plate 43, figure 10

Nodosaria spinicosta D'ORBIGNY, *1846*, Foram. Foss. Bassin Tertiaire, Vienne, p. 37, pl. 1, figs. 32, 33; CUSHMAN, *1927*, Jour. Paleontology, vol. 1, pt. 2, p. 154, pl. 24, figs. 5, 6 (Alazan, Mexico).

The Haitian specimen resembles d'Orbigny's figure except that the ribs tend to break up on the lower part of the chambers above the pendant spinous border margining the neck-like extension. The initial spine is not preserved. Length of the figured specimen, 0.4 mm.

Genus LENTICULINA Lamarck, 1804

LENTICULINA PEREGRINA (Schwager)
Plate 43, figures 13, 14

Cristellaria peregrina SCHWAGER, *1866*, Novara-Reise, geol. Theil, vol. 2, p. 245, pl. 7, fig. 89; CUSHMAN, *1923*, U. S. Nat. Mus. Bull. 104, pt. 4, p. 113, pl. 30, figs. 3, 4.

Test compressed, coiled, with few chambers, the last one tending to become evolute, and slightly dwarfed; chambers increasing greatly in height as added, four or five visible; sutures slightly curved, flush with surface, generally distinct, not limbate; a narrow, thin keel, generally somewhat broken on the early chambers, slightly wider around the periphery margin of the last chamber and includes the aperture which is slightly produced and radiate; the early apertural position peripheral, the last one nearly central and terminal; penultimate aperture showing through the thin translucent test-wall. The larger specimen figured is 0.55 mm. long, 0.38 mm. wide, and 0.19 mm. thick.

The Haitian specimens are referred to this species even though the last chamber is somewhat smaller, and the aperture not so centrally located or so large and conspicuous.

Genus LINGULINA d'Orbigny, 1826

LINGULINA TRICRENATA
Coryell and Rivero, n. sp.
Plate 41, figures 12a–c

Test small, only slightly compressed, in front view very broadly ovoid, narrowing slightly towards apertural end; in side view very broadly elliptical, slightly pointed at apertural end and modified by faint keels at aboral end; cross-section very broadly elliptical, short diameter about four-fifths of the long one; three chambers visible, the first two indicated coiling, the last chamber forming most of the test; three faint keels on aboral end, parallel to plane of compression, dying out about $\frac{2}{3}$ of the distance towards the aperture; wall smooth, very finely perforate; aperture terminal, fissurine, elongate in the direction of compression, not radiate. Length, 0.41 mm.; long diameter, 0.36 mm.; short diameter, 0.28 mm.

This species is quite like *Lingulina cubensis* Cushman and Bermudez. The latter is different in having a distinct single sharp

keel and shows three coiled chambers before the last large chamber.

Genus MARGINULINA d'Orbigny, 1826
MARGINULINA PAPILLATA Coryell and Rivero, n. sp.
Plate 43, figures 6a–b

Test somewhat compressed, with a narrow keel on the periphery; very evolute, but only the last chamber with uncurved margins, even though the last four chambers have a free inner edge. Sutures are ornamented with aligned nodes, and the surface of the chambers is marked by a scattered occurrence of them except on the last chamber where the nodes are so depressed that the surface appears almost smooth. Aperture raised and near the periphery on the last septal face. Length 1.10 mm., width 0.7 mm., thickness 0.6 mm.

MARGINULINA PEDIFORMIS Bornemann
Plate 41, figure 14

Marginulina pediformis BORNEMANN, *1855*, Deutsche geol. Gesell. Zeitschr., vol. 7, p. 326, pl. 13, fig. 13; COLE and PONTON, *1930*, Florida Geol. Survey Bull. 5, p. 32, pl. 7, figs. 3, 4; ELLISOR, *1933*, Am. Assoc. Petroleum Geologists Bull., vol. 17, no. 11, pl. 7, fig. 4; NUTTALL, *1935*, Jour. Paleontology, vol. 9, no. 2, p. 125, pl. 14, fig. 17.

This species occurs in the Marianna (Oligocene) limestone of Florida, Jackson (Eocene) formation of western Gulf Coast the Pauji shale of Eocene age in Venezuela as well as in the Haitian collections. The morphotypes have introduced less regularity into the general form of the species than that illustrated by Bornemann. Length of figured specimen, 0.52 mm.; width, 0.25 mm.; thickness, 0.30 mm.

MARGINULINA SUBCRASSA Schwager
Plate 41, figure 19

Marginulina subcrassa SCHWAGER, *1866*, Novara-Reise, geol. Theil, vol. 2, p. 240, pl. 6, fig. 82; CUSHMAN, *1933*, U. S. Nat. Mus. Bull. 161, pt. 2, p. 9, pl. 2, figs. 11a–b.

The Haitian occurrence extends the range below the horizon of the holotype, which was reported from the Pliocene of Kar Nikobar. Length of figured specimen, 0.50 mm., width, 0.19 mm., thickness, 0.17 mm.

MARGINULINA HOWEANA Coryell and Rivero, n. sp.
Plate 41, figure 13

This species resembles somewhat in shape the trochoid *Marginulina ? sp.*(*C.*) of Howe and Wallace from the Jackson at Danville Landing, La., but has fewer chambers, and the sutures do not form a "loop" at earlier apertures as in their figure.

Dimensions of the figured specimen, length, 0.57 mm., width, 0.26 mm.

Genus NODOSARIA Lamarck, 1812
NODOSARIA ACULEATA d'Orbigny
Plate 42, figure 16

Nodosaria aculeata D'ORBIGNY, *1846*, Foram. Foss. Bassin Tertiaire, Vienne, p. 35, pl. 1, figs. 26, 27; CUSHMAN, *1927*, Jour. Paleontology, vol. 1, no. 2, p. 154, pl. 24, fig. 4 (Alazan, Mexico); —, *1927*, Cushman Lab. Foram. Research Contr., vol. 3, no. 49, p. 166.

The Haitian specimens have chambers slightly more separated than those shown in the figures of d'Orbigny. Even though no marginuline forms with features like this species were encountered in our collection it seems more convenient to use for the present the identification as given here. Length of figured specimen, 0.78 mm.

NODOSARIA ACUTA (d'Orbigny)
Plate 42, figure 6

Dentalina acuta D'ORBIGNY, *1846*, Foram. Foss. Bassin Tertiaire, Vienne, p. 56, pl. 2, figs. 40–43.

The Haitian specimen has a few more costae than d'Orbigny's figure. Length of the figures specimen, 1.25 mm.

NODOSARIA CONSOBRINA (d'Orbigny)
Plate 41, figures 17, 23

Dentalina consobrina D'ORBIGNY, *1846*, Foram. Foss. Bassin Tertiaire Vienne, p. 46, pl. 2, figs. 1–3; CUSHMAN, *1929*, Cushman Lab. Foram. Research Contr., vol. 5, pt. 4, p. 86, pl. 12, figs. 27–29.

Nodosaria consobrina GALLOWAY and MORREY, *1929*, Bull. Am. Paleontology, vol. 15, no. 55, p. 15, pl. 1, fig. 13.

The Haitian specimens are fragmentary and referred to this species on the basis of the shape of the chambers. The species is reported to range from the Jurassic to Recent. Lengths of the figured specimens 1.25 mm. (fig. 23) and 1.15 mm. (fig. 17).

NODOSARIA ELEGANTISSIMA
(d'Orbigny)
Plate 42, figure 15

Dentalina elegantissima D'ORBIGNY, *1846*, Foram. Foss. Bassin Tertiaire, Vienne, p. 55, pl. 2, figs. 33–35.

The Haitian specimen is very much like d'Orbigny's figure in its general shape, and differs from it in having seven instead of six costa. Length of the figured specimen, 0.75 mm.

NODOSARIA EWALDI Reuss
Plate 42, figures 10, 11

Nodosaria ewaldi REUSS, *1851*, Deutsche geol. Gesell. Zeitschr., vol. 3, pl. 3, fig. 2; CUSHMAN, *1927*, Jour. Paleontology, vol. 1, no. 2, p. 153, pl. 24, figs. 1, 2 (Alazan, Mexico); —, *1935*, U. S. Geol. Survey Prof. Paper 181, p. 22, pl. 9, fig. 2 (Jackson).

The Haitian specimens seem to be quite like the morphotype of this species, notwithstanding the fragmental condition.

Dimensions of figured specimens: lengths 1.6 mm., and 1.35 mm., diameters, 0.48 mm. and 0.25 mm.

NODOSARIA SETOSA Schwager

Nodosaria setosa SCHWAGER, *1866*, Novara-Reise, geol. Theil, vol. 2, p. 216, pl. 5, fig. 40.

This species is represented in the Haitian material by only a few specimens. The fragments are usually shorter and with less chambers than that shown in the figure of the type.

NODOSARIA HELICATA Coryell and Rivero, n. sp.
Plate 42, figures 7, 8

A nodosarian form with slightly depressed sutures, with the entire surface of the specimen ornamented with fine spiral costae, that cross the diameter of lineal arrangement of chambers in a distance of four chambers. The number of costae increase by intercalation and bifurcation. The aperture is broken. Length of figured specimens, figure 7, 1.25 mm., figure 8, 1.3 mm.

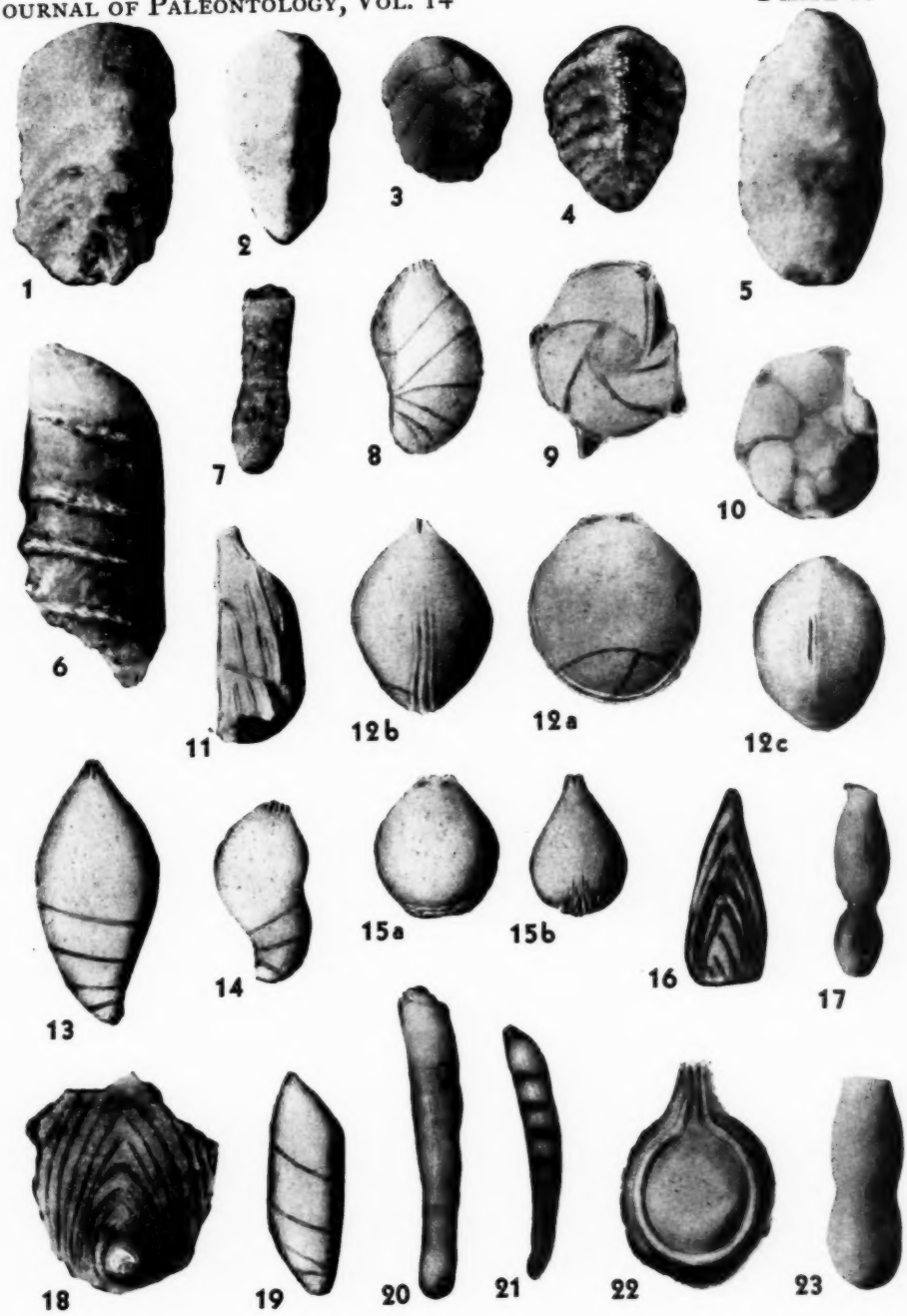
NODOSARIA OBLIQUA (Linnaeus)
Plate 42, figure 17

Nautilus obliqua LINNAEUS, *1758*, Systema naturae, ed. 10, p. 711.
Nodosaria (Dentaline) obliqua D'ORBIGNY, *1826*, Annales Sci. Nat., Paris, F. ser. 1, tome 7, p. 253, fig. 5.
Nodosaria (Dentalina) obliqua PARKER and JONES, *1859*, Annals and Mag. Nat. History, 3d ser., vol. 3, p. 482.
Nodosaria obliqua H. B. BRADY, *1884*, Challenger Rept., Zool., vol. 9, p. 513, pl. 64, figs. 20–22; CUSHMAN, *1922*, U. S. Geol. Survey Prof. Paper 129-F, p. 129, pl. 30, figs. 6, 7.

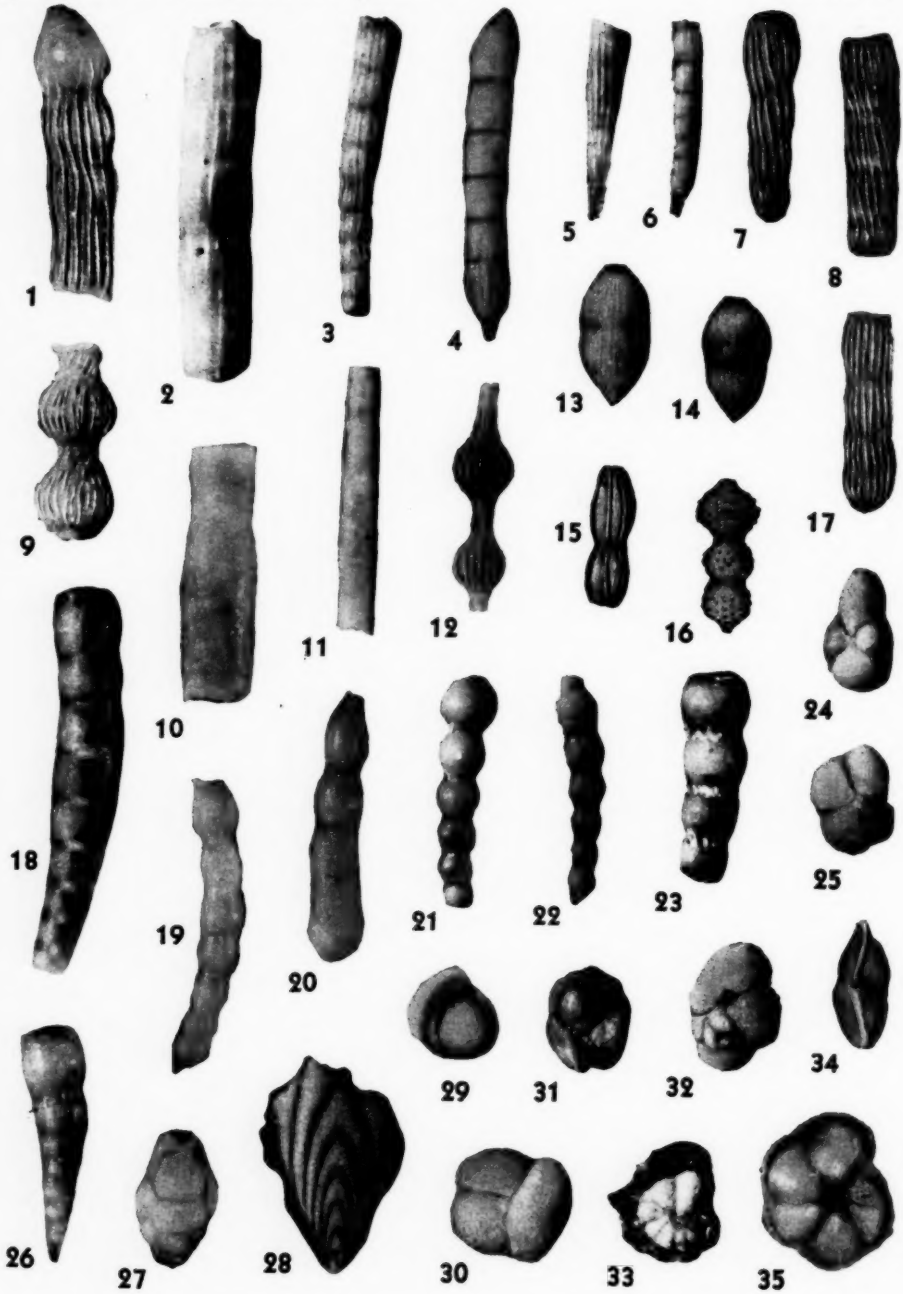
The Haitian specimens are rather stout forms with numerous strong costae. The sutures are obscure, only slightly depressed in some of the specimens. Length of the figured specimen, 1.25 mm.

EXPLANATION OF PLATE 41

FIGS. *1*—*Vulvulina spinosa miocenica* Cushman, ×30 (p. 325)
2—*Gaudryina (Pseudogaudryina) atlantica*, ×23 (p. 325)
3—*Textularia lythostrotum* (Schwager), ×25 (p. 324)
4—*Textularia warreniles* Coryell and Rivero, n. sp., ×30 (p. 325)
5—*Dorothia caribaea* Cushman, ×30 (p. 325)
6—*Vaginulina robusta* Plummer ×23 (p. 333)
7—*Listerella nodulosa* (Cushman), ×22 (p. 326)
8—*Saracenaria acutauricularis* (Fichtel and Moll), ×24 (p. 332)
9—*Robulus calcar* (Linnacus), ×36 (p. 332)
10—*Darbyella* sp., ×25 (p. 335)
11—*Vaginulina obliquata* Coryell and Rivero, n. sp., ×23 (p. 333)
12a–c—*Lingulina tricrenata* Coryell and Rivero, n. sp., ×65 (p. 328)
13—*Marginulina howeana* Coryell and Rivero, n. sp., ×65 (p. 329)
14—*Marginulina pediformis* Bornemann, ×50 (p. 329)
15a–b—*Fissurina crenulata* Coryell and Rivero, n. sp., ×21 (p. 327)
16—*Frondicularia tenuissima* Hantken, 1875 ×30 (p. 327)
17, 23—*Nodosaria consobrina* (d'Orbigny), ×21 (p. 328)
18—*Frondicularia bulbosa* Coryell and Rivero, n. sp., ×25 (p. 327)
19—*Marginulina subcrassa* Schwager, ×60 (p. 329)
20–21—*Dentalina pauperata* d'Orbigny, ×34 (p. 326)
22—*Lagena orbignyana caribaea* Cushman, ×75 (p. 327)



Coryell and Rivero, Miocene Foraminifera



Coryell and Rivero, Miocene Foraminifera

NODOSARIA SUBLINEATA Coryell and Rivero, n. sp.
Plate 42, figure 2

A nodosarian Haitian specimen with rather numerous faint costae that are continuous over several chambers, then dying out as others are intercalated, has been assigned to this species. The sutures are slight transverse depressions. Length of the figured specimen, 2.30 mm.

NODOSARIA RADICULA (Linnaeus)
Plate 43, figure 16

Nautilus radicula LINNAEUS, *1758*, Systema naturae, ed. 10, tomi 1, 2, p. 711; PLANCUS, Conch., 14, t. I, fig. 5.
Nodosaria radicula CORYELL and EMBICH, *1937*, Jour. Paleontology, vol. 11, no. 4, p. 298, pl. 42, fig. 10.

The Haitian specimen has chambers somewhat longer than those from Panama assigned to the same species. Length of specimen, 2.1 mm.

NODOSARIA SKOBINA Schwager
Plate 42, figure 5

Nodosaria skobina SCHWAGER, *1866*, Novara-Reise, geol. Theil, vol. 2, p. 225, pl. 5, fig. 56.

A specimen increasing rapidly in diameter, with numerous not very heavy costae which bifurcate as the diameter increases. Length of figured specimen, 1.2 mm.

Genus OOLINA d'Orbigny
OOLINA STRIATA (d'Orbigny)
Plate 43, figure 11

Oolina striata D'ORBIGNY, *1839* (1843), Voyage Am. Merid., vol. 5, pt. 5, p. 21, pl. 5, fig. 12; REUSS, *1862*, Akad. Wiss. Wien, Math.-Naturwiss. Kl., Sitzungsber., vol. 46, 1862, p. 327, pl. 4, figs. 46, 47.

The specimen is extremely finely striated, the striations only appearing under high magnification. The neck of the Haitian specimen is somewhat larger and shorter than that shown in the figure of the type. Length of the specimen, 0.4 mm.

Genus PSEUDOGLANDULINA Cushman, 1929
PSEODOGLANDULINA TROCHOFORMIS Coryell and Rivero, n. sp.
Plate 42, figures 13, 14

The test is marked by numerous longitudinal, very fine, striations; the sutures are only slightly depressed; the proximinal end is broadly tapering forming an angle only slightly less than a right angle. Lengths of figured specimens, 0.7 mm. and 0.65 mm.

Nodosaria comatula Cushman, has fewer longitudinal ridges and a rounded initial termination.

Pseudoglandulina gallowayi Cushman, has much fewer and stouter costae and *P. comata* (Batsch) is initially more slender and more rounded than the Haitian species.

EXPLANATION OF PLATE 42

FIGS. *1, 3—Dentalina vertebralis* (Batsch), ×22 (p. 327)
2—Nodosaria sublineata Coryell and Rivero, n. sp., ×21 (p. 331)
4—Dentalina seminuda Reuss, ×30 (p. 327)
5—Nodosaria skobina Schwager, ×25 (p. 331)
6—Nodosaria acuta (d'Orbigny), ×22 (p. 329)
7, 8—Nodosaria helicata Coryell and Rivero, n. sp., ×23 (p. 330)
9—Lagenonodosaria sigmoidea Coryell and Rivero, n. sp., ×25 (p. 328)
10, 11—Nodosaria ewaldi Reuss, ×30, ×23 (p. 330)
12—Lagenonodosaria extensa Coryell and Rivero, ×22 (p. 328)
13–14—Pseudoglandulina trochoformis Coryell and Rivero, n. sp., ×30 (p. 331)
15—Nodosaria elegantissima d'Orbigny, ×27 (p. 330)
16—Nodosaria aculeata d'Orbigny, ×27 (p. 329)
17—Nodosaria obliqua (Linnaeus), ×23 (p. 330)
18–20, 26—Nodosarella verneuili (d'Orbigny), ×25 (p. 344)
21–23—Nodosarella paucistriata Galloway and Morrey, ×23 (p. 343)
24, 25, 32—Globigerinoides sacculifera (Brady), ×23 (p. 340)
27—Uvigerina quadrata Coryell and Rivero, n. sp., ×23 (p. 343)
28—Plectofrondicularia vaughani, Cushman ×30 (p. 341)
29–30—Globigerina haitiensis Coryell and Rivero, n. sp., × 23 (p. 339)
31—Globigerina altispira Cushman and Jarvis, ×30 (p. 339)
33—Laticarinina pauperata (Parker and Jones), ×20 (p. 333)
34, 35—Globorotalia menardii (d'Orbigny), ×25 (p. 336)

Genus ROBULUS Montfort, 1808
ROBULUS CALCAR (Linnaeus)
Plate 41, figure 9

Nautilus calcar LINNAEUS, *1758*, Systema naturae, ed. 10, p. 709.
Cristellaria calcar CUSHMAN, *1923*, U. S. Nat. Mus. Bull. 104, pt. 4, p. 115, pl. 31, fig. 4.
Robulus calcar GALLOWAY and MORREY, *1929*, Bull. Am. Paleontology, vol. 15, no. 55, p. 20, pl. 2, figs. 10a–b; CUSHMAN, *1929*, Cushman Lab. Foram. Research Contr., vol. 5, pt. 4, p. 84, pl. 12, fig. 18.

This species is rather rare in the Haitian collection. It ranges from the Tertiary to the Recent. It has been recorded from the Miocene of Ecuador, Venezuela, Trinidad and Jamaica. Length of figured specimen, 0.70 mm., width, 0.55 mm.

ROBULUS CLERICII (Fornasini)
Plate 43, figures 7a–b

Cristellaria clericii FORNASINI, *1895*, "Cristellaria clericii n. sp.," Bologna, text fig.; —, *1901*, Accad. sci. Ist. Bologna Mem., ser. 5, vol. 9, p. 65, fig. 17 (in text).
Robulus clericii CUSHMAN, *1929*, Cushman Lab. Foram. Research Contr., vol. 5, pt. 4, p. 84, pl. 12, figs. 16, 17.

This species is rather common in the Haitian material. The larger specimens are somewhat involute, showing some of the earlier chambers through the umbo. In some of the specimens the neck which connects the alar umbonal lobe with the main body of the chambers is so narrow that these lobes appear almost as separate chamberlets, forming a central rosette.

R. clericii has been recorded from the Neogene of Italy, Tertiary of Barbadoes, Naparima Miocene of Trinidad, younger Tertiary of Ecuador and Venezuela. It also occurs in collections from the Bowden marls (Miocene). Length of the figured specimen, 0.64 mm.

ROBULUS DEFORMIS (Reuss)
Plate 43, figure 18

Robulina deformis REUSS, *1851*, Deutsche. geol. Gesell. Zeitschr., vol. 3, p. 70, pl. 4, fig. 30.
Robulus cf. *deformis* GALLOWAY and MORREY, *1929*, Bull. Am. Paleontology, vol. 15, no. 55, p. 21, pl. 2, figs. 11a–b.

The Haitian specimens are apparently similar to the morphotype of Galloway and Morrey and only slightly different from the figure of the holotype. The figured specimen has the following dimensions: length, 0.80 mm., thickness, 0.45 mm.

ROBULUS OBLONGUS Coryell and Rivero, n. sp.
Plate 43, figures 12a–b

Test about $1\frac{1}{3}$ times as long as wide, apertural end somewhat produced; thickness is about one-half the width; periphery sharp, and slightly keeled; 6 to 8 chambers visible, increasing in height as added; sutures gently curved, slightly limbate but not raised, extending into umbilicus, no central umbo, chambers completely involute; in edge view, apertural face makes up about half the test; apertural face equitant, flat, with the margins raised; aperture radiate with large robuline slit; earlier apertures showing conspicuously through shell. Length, 0.85 mm., width, 0.62 mm., thickness, 0.31 mm.

This species is rather common in the Haitian locality.

ROBULUS LIMBOSUS (Reuss)
Plate 43, figures 17a–b

Robulina limbosa REUSS, *1863* (1864), Akad. Wiss. Wien, Math. Naturwiss Kl., Sitzungsber., vol. 48, pt. 1, p. 55, pl. 6, figs. 69a–b.
Robulus limbosus CUSHMAN, *1933*, U. S. Nat. Mus. Bull. 161, pt. 2, p. 3, pl. 1, figs. 4, 6; pl. 2, figs. 5a–b; ELLISOR, *1933*, Am. Assoc. Petroleum Geologists Bull., vol. 17, no. 11, pp. 1293–1350, pl. 2, figs. 1a–b; CUSHMAN, *1935*, U. S. Geol. Survey Prof. Paper 181, p. 16, pl. 6, fig. 5.

Robulus limbosus is quite common in the Haitian material. The figured morphotypes of authors show distinct variations from the original figure and from one another. The Haitian specimen is very much like the tropical Pacific forms. Dimension of the figured specimens: height, 0.80 mm., width, 0.72 mm., thickness, 0.40 mm.

Genus SARACENARIA Defrance, 1824
SARACENARIA ACUTAURICULARIS
(Fichtel, and Moll)
Plate 41, figure 8

Natutilus acutauricularis FICHTEL and MOLL, 1798, Wien. Österreich, p. 102, pl. 18, figs. g–i.
Saracenaria acutauricularis CUSHMAN, *1929*, Cushman Lab. Foram. Research Contr., vol. 5, pt. 4, p. 88, pl. 13, fig. 12; —, *1930*, Florida Geol. Survey Bull. 4, p. 27, pl. 4, figs. 10a–b.

Besides being found in the Haitian col-

lections this species occurs in the Choctawhatchee and Shoal River beds of Florida, the younger Tertiary of Venezuela and Trinidad. The older forms from the Jurassic are apparently not correctly identified. The figured specimen has a length of 1.15 mm.

Genus VAGINULINA d'Orbigny, 1826

VAGINULINA OBLIQUATA Coryell and Rivero, n. sp.

Plate 41, figure 11

A broken specimen represents this species. It is somewhat compressed laterally, with oblique and slightly depressed sutures; aperture marginal; ornamented by thin, sharp, slightly oblique, longitudinal costae which die out on the terminal chamber or as they approach the margin. Length 1.3 mm.; width 0.5 mm.; thickness, 0.3 mm.

VAGINULINA CLAVATA (Costa)

Vaginulina clavata COSTA, *1855* (1857), Accad. Sci. Napoli Mem., vol. 2, p. 145, pl. 2, fig. 18A–B; CUSHMAN and JARVIS, *1930*, Jour. Paleontology, vol. 4, no. 4, p. 359, pl. 32, fig. 12.

The Haitian specimen is very similar to Cushman and Jarvis' material, but somewhat smaller. Their figure of the Miocene specimen does not show the cross-section of the species. Length of the Haitian example 0.7 mm.

VAGINULINA ROBUSTA Plummer

Plate 41, figure 6

Vaginulina robusta PLUMMER, *1926*, Texas Univ. Bull., Bur. Econ. Geology, p. 12, pl. 6, figs. 34a–b.

A single broken specimen of a very large stout *Vaginulina* forms the Haitian representative that resembles *V. robusta* Plummer. The sutural ridges are developed only on the middle of the flattened sides, not extending to the marginal periphery. Length of the specimen 2.1 mm.

Family NONIONIDAE Reuss, 1860

Genus LATICARININA Galloway and Wissler, 1927

LATICARININA ANGUSTATA Coryell and Wivero, n. sp.

Plate 43, figures 15a–b

Test of moderate size for the genus, compressed and keeled, with later chambers inflated; early chambers closely appressed but apparently not involute, later ones loosely appressed; chambers increasing in height, the last one forming about one-third of the test; early sutures covered with a few thick beads of shell material, the latter ones nearly flush with the sutures, the last two chambers very much inflated between the sutures; the apertural face of the last chamber is broken. Length, 0.75 mm., width, 0.56 mm., thickness, 0.27 mm.

LATICARININA PAUPERATA (Parker and Jones)

Plate 42, figure 33

Pulvinulina repanda menardii pauperata PARKER and JONES, *1865*, Philos. Trans., vol. 155, p. 395, pl. 16, figs. 50, 51.

Pulvinulina pauperata H. B. BRADY, *1884*, Challenger Rept., Zool., vol. 9, p. 696, pl. 104, figs. 3–11; NUTTALL, *1928*, Geol. Soc. London Quart. Jour., vol. 84, p. 100.

Laticarinina pauperata CUSHMAN, *1931*, U. S. Nat. Mus. Bull. 104, pt. 8, p. 114, pl. 20, figs. 4a–c; pl. 21, figs. 1a–c.

This species is rather rare in the Haitian material. It is known to range from the Miocene to Recent.

The diameter of the figured specimen, 0.75 mm.

Genus NONION Montfort, 1808

NONION POMPILIOIDES (Fichtel and Moll)

Nautilus pompilioides FICHTEL and MOLL, *1798*, Tert. Micr., p. 31, pl. 2, figs. a–c.

Nonion pompilioides GALLOWAY and MORREY, *1929*, Bull. Am. Paleontology, vol. 15, no. 55, p. 43, pl. 6, fig. 15; CUSHMAN, *1929*, Cushman Lab. Foram. Research Contr., vol. 5, pt. 4, p. 83, pl. 13, figs. 25a–b; COLE, *1931*, Florida Geol. Survey Bull. 6, p. 32, pl. 6, fig. 2; CUSHMAN and CAHILL, *1933*, U. S. Geol. Survey Prof. Paper 175-A, p. 21, pl. 7, figs. 5a–b.

This species has a known range extending through the Miocene and younger beds. It is usually considered as a deep water species although recorded occasionally from shallow depths. The Haitian specimens seems to fit in the latter environment.

Genus PULLENIA Parker and Jones, 1862

PULLENIA QUINQUELOBA (Reuss)

Nonionina quinqueloba REUSS, *1851*, Deutsche geol. Gesell. Zeitschr., vol. 3, p. 71, pl. 5, fig. 31.

Pullenia quinqueloba CUSHMAN, *1924*, U. S. Nat. Mus. Bull. 104, pt. 5, p. 42, pl. 8, figs. 5–9, 11; GALLOWAY and MORREY, *1929*, Bull. Am. Paleontology, vol. 15, no. 55, p. 44, pl. 6, fig. 17.

This species ranges from Eocene to Recent. Only a few specimens are present in the Haitian sample. The recent forms live chiefly in deep, cold water.

Family ROTALIIDAE Reuss, 1860
Genus ANOMALINA d'Orbigny, 1826
ANOMALINA FLINTII Cushman
Plate 44, figures 8a–c

Anomalina ammonoides FLINT (not Reuss), *1899*, U. S. Nat. Mus. Ann. Rep., p. 335, pl. 78, fig. 4.
Anomalina flintii CUSHMAN, *1931*, U. S. Nat. Mus. Bull. 104, pt. 8, p. 108, pl. 18, figs. 5a–c.

The Haitian specimens are closely similar to Cushman's recent examples from the Albatross station D2352, 22°35′ N., 84°23′ W. in 463 fathoms with a bottom temperature 45°F.

Dimensions of the figured specimen; longer diameter, 0.61 mm.; shorter diameter, 0.45 mm.; thickness, 0.22.

ANOMALINA NUCLEATA (Seguenza)
Plate 44, figures 2a–c

Truncatulina nucleata SEGUENZA, *1880*, Accad. Lincei Atti, ser. 3, vol. 6, p. 64, pl. 7, figs. 8a, b (Lower Miocene).
Cibicides nucleata GALLOWAY and MORREY, *1929*, Bull. Am. Paleontology, vol. 15, no. 55, p. 31, pl. 4, fig. 9.

This species is common in Haitian material. The whorls are nearly completely involute on the ventral side and less involute on the dorsal side.

Dimensions of the figured specimen; longer diameter, 0.95 mm.; shorter diameter, 0.85 mm.

Genus CIBICIDES Montfort, 1808
CIBICIDES CONCENTRICUS (Cushman)
Plate 44, figures 9a–c

Truncatulina concentrica CUSHMAN, *1918*, U. S. Geol. Survey Bull. 676, p. 64, pl. 21, fig. 3.
Cibicides concentricus CUSHMAN, *1930*, Florida Geol. Survey Bull. 4, p. 61, pl. 12, figs. 4a–c; CUSHMAN and PONTON, *1932*, Florida Geol. Survey Bull. 9, p. 101; CUSHMAN, *1931* (sp. *concentrica*), U. S. Nat. Mus. Bull. 104, pt. 8, p. 120, pl. 21, figs. 4, 5; pl. 22, figs. 1, 2; CUSHMAN and CAHILL, *1933*, U. S. Geol. Survey Prof. Paper 175-A, p. 35, pl. 13, figs. 3a–c.

The species is represented by a few specimens in the Haitian sample. It occurs in the Miocene of the Gulf and Atlantic coastal plain deposits, and is still living off the coast of Florida in shallow water.

Dimension of the figured specimen: length, 0.48 mm., thickness, 0.15 mm.

CIBICIDES FLORIDANUS (Cushman)
Plate 44, figures 10a–c

Truncatulina floridana CUSHMAN, *1918*, U. S. Geol. Survey Bull. 676, p. 62, pl. 19, fig. 2; NUTTALL, *1928*, Geol. Soc. Quart. Jour., vol. 84, p. 98, pl. 7, figs. 14, 16.
Cibicides floridanus CUSHMAN, *1930*, Florida Geol. Survey Bull. 4, p. 61, pl. 12, figs. 3a–c; CUSHMAN and LAIMING, *1931*, Jour. Paleontology, vol. 5, p. 119, pl. 14, figs. 8a–c; CUSHMAN and PARKER, *1931*, Cushman Lab. Foram. Research Contr., vol. 7, p. 16, pl. 3, figs. 2a–c; CUSHMAN and PONTON, 1932, Florida Geol. Survey Bull. 9, p. 100. (C. floridana); CUSHMAN, *1931*, U. S. Nat. Mus. Bull. 104, pt. 8, p. 122, pl. 23, figs. 3–5; CUSHMAN and CAHILL, *1933*, U. S. Geol. Survey Prof. Paper. 175-A, p. 34, pl. 13, figs. 1a–c.

This species with its morphotypes shows considerable variation. More detailed study might reveal need for reclassification; however, under its present arrangement there are many specimens in the Haitian material that can be referred here. The raised sutures, somewhat angulated periphery, with about 10–12 chambers in the last whorl of the dextrally coiled, approximately biconvex test, seem to be some of the outstanding characteristics. The aperture is peripheral, extending slightly on the dorsal side and more on the ventral side; wall is coarsely punctate.

Dimension of the figured specimen: diameter, 0.7 mm., thickness, 0.3 mm.

CIBICIDES IO (Cushman)
Plate 44, figures 11a–c

Truncatulina tenera FLINT (not H. B. Brady), *1899*, U. S. Nat. Mus. Ann. Rept., 1897, p. 334, pl. 77, fig. 4.
Cibicides pseudoungeriana io CUSHMAN, *1931*, U. S. Nat. Mus. Bull. 104, pt. 8, p. 125, pl. 23, figs. 1, 2.

There is considerable variation evident in the specimens assigned to this species. Some are thick, as the figured specimen; some are thinner with a sharper periphery. Cushman records this form from the northern part of the Gulf of Mexico from 40 to 1330 fathoms.

Dimensions of the figured specimen: longer diameter, 0.46 mm., thickness, 0.23 mm.

CIBICIDES SINISTRALIS Coryell and Rivero, n. sp.
Plate 44, figures 12a–c

Test sinestrally coiled, biconvex, periphery somewhat keeled; about 3½ whorls of the dorsal spiral are visible through a transparent deposit; chambers increase regularly in height as added with 10 to 12 in the last whorl; dorsal sutures slightly oblique and limbate merging into the narrow peripheral keel; the last few sutures raised; earlier ventral sutures broadly curved backward, the later one somewhat sigmoid; ventral surface smooth; the umbilicus filled with hyaline carbonate; aperture small, cibicidally peripheral, with a slight lip; wall coarsely perforate, thin, translucent.

Dimensions of the figured specimen: diameter 0.6 mm., thickness, 0.25 mm.

CIBICIDES ROBERTSONIANUS HAITIENSIS Coryell and Rivero, n. sp.
Plate 44, figures 4a–c, 5, 6

The Haitian specimens have a test somewhat unequally biconvex; the dorsal less and more evenly, the ventral strongly convex near the periphery and less so toward the umbilicus; periphery more broadly rounded in mature specimens and narrowly rounded to subacute in the younger stages; 4.5 to 5 whorls of the spire are visible through the dorsal external deposit, with 9 to 11 chambers in the last whorl; the chambers increase gradually in height and length as added. The dorsal sutures are slightly curved, flush with the surface and somewhat less conspicuous than the spiral suture; the ventral side is umbilicated in mature specimens, with subradial, gently curved, flush, sutures; the aperture is small, and peripheral; the wall is more coarsely perforate on the dorsal side.

Dimensions: diameter varies from 0.4 to 0.56 mm.; thickness from 0.2 to 0.3 mm. Figure 4 has the larger measurements. It is a microspheric form. Megalospheric form (fig. 5) has a diameter of 0.44 mm. and a thickness of 0.25 mm. Figure 6 has a diameter of 0.53 mm. and a thickness of 0.23 mm.

This species is quite abundant in the Haitian collection.

CIBICIDES PERFORATUS Coryell and Rivero, n. sp.
Plate 44, figures 13a–c

Test of medium size, biconvex, rather compressed, with nearly a circular lateral outline, rarely slightly lobulated on the last few chambers; periphery acute and keeled at least in the early stages; central dorsal spiral is obscured by an acervuline thickening that is confluent with the prominently raised deposits of the gently curved, broadly limbate dorsal sutures; 9 to 12 chambers form the last whorl; the dorsal lateral loculate surfaces are coarsely and conspicuously perforated; ventrally the last whorl is completely involute with chambers separated by broadly limbate raised sutures composed of clear shell material that is confluent in the umbilicate area; the chamber surfaces between the ventral sutures is finely perforate in contrast to the dorsal side; the aperture is small and peripheral.

Dimensions of the type specimen: diameter, 0.5 mm., thickness, 0.2 mm.

The very broadly limbate character of the sutures with the thickening over the dorsal coil, the coarsely dorsal perforations and inconspicuous ventral ones, the keeled periphery, and the contrast of the clear shell material of the sutures with the rest of the test, are distinctive features and distinguish this species from forms assigned to *C. pseudoungerianus* and *C. floridanus*.

Genus DARBYELLA Howe and Wallace, 1933
DARBYELLA sp.
Plate 41, figure 10

The Haitian material contains a single specimen that seems to belong to this genus. We were uncertain as to its specific determination until more material could be studied.

Diameter of figured specimen, 0.95 mm.

Genus EPONIDES Montfort, 1808
EPONIDES ANTILLARUM (d'Orbigny)

Rotalina anteillarum D'ORBIGNY, *1839*, in de la Sagra, Hist. Physique Pol. Nat. Cuba, Foram., p. 75, pl. 5, figs. 4–6.

Eponides antillarum CUSHMAN and JARVIS, *1930*, Jour. Paleontology, vol. 4, no. 4, p. 364, pl.

33, figs. 14a–c; pl. 34, fig. 2; CUSHMAN, *1931*, U. S. Nat. Mus. Bull. 104, pt. 8, p. 42, pl. 9, figs. 2a–c; CUSHMAN and PONTON, *1932*, Florida Geol. Survey Bull. 9, p. 93, pl. 14, figs. 1a–c.

Pulvinulina incerata CUSHMAN, *1932*, Carnegie Inst. Washington, Pub. 311, p. 51, pl. 9, figs. 1–3.

Several specimens of this species were found in the Haitian material. It occurs also in the Bowden formation in Jamaica, Miocene (in middle zone of Shoal River and a single station in the Chipola) of Florida and as a recent species near Florida in depths varying from 20 to 159 fathoms.

EPONIDES PRAECINCTUS (Karrer)
Plate 43, figures 25a–c

Rotalia praecincta KARRER, *1868*, Akad. Wiss. Wien., Math.-naturwiss. Kl., Sitzungsber., vol. 58, Abt. 1, p. 189, pl. 5, fig. 7.

Truncatulina praecincta, BRADY, *1884*, Challenger Rept., Zool., vol. 9, p. 667, pl. 95, figs. 1–3; CUSHMAN, *1919*, Carnegie Inst. Washington, Publ. 291, p. 41; —, *1921*, U. S, Nat. Mus. Bull. 100, p. 318.

The species ranges from Miocene to Recent. It has been reported from the Miocene of Hungary, Jamaica, Italy, and Santo Domingo; Pliocene of Italy, and Recent in a number of tropical and subtropical regions, where it occurs mostly between 100 and 500 fathoms. *Eponides praecinatus* as represented in the Haitian form differs from *E. guayabalensis yeguaensis* Weinzierl and Applin in having less chambers in the last whorl, dorsal sutures more oblique, the ventral ones less curved, and the limbate and raised character more pronounced.

Diameter of the Haitian figured specimen, 0.8 mm., thickness 0.5 mm.

EPONIDES UMBONATUS (Reuss)
Plate 43, figures 21a–c

Rotalina umbonata REUSS, *1851*, Deutsche geol. Gesell. Zeitschr., vol. 3, p. 75, pl. 5, figs. 35a–c.

Eponides umbonata CUSHMAN, *1929*, Cushman, Lab. Foram. Research Contr., vol. 5, pt. 4, p. 98, pl. 14, figs. 8a–c; —, *1931*, U. S. Nat. Mus. Bull. 104, pt. 8, p. 52–54, pl. 11, figs. 1–3.

Rotalia umbonata GALLOWAY and MORREY, *1929*, Bull. Am. Paleontology, vol. 15, no. 55, p. 26, pl. 4, fig. 1.

Truncatulina tenera H. B. BRADY, *1884*, Challenger Rept., Zool., vol. 9, p. 665, pl. 95, figs. 11a–c.

Rotalia ecuadorensis GALLOWAY and MORREY, *1929*, Bull. Am. Paleontology, vol. 15, no. 55, p. 26, pl. 3, figs. 13a–c.

Specimens of this species occur fairly frequently in the Haitian material. It ranges from the Eocene to the Recent. The Recent representatives are found chiefly in deep water varying from 100 to over 1000 fathoms.

Dimensions of the figured specimen: diameter, 0.64 mm., thickness, 0.35 mm.

Genus GLOBOROTALIA Cushman 1927
GLOBOROTALIA CANARIENSIS
(d'Orbigny),
Plate 43, figures 27a–c

Rotalia canariensis D'ORBIGNY, *1839*, in Barker, Webb and Berthelot, Hist. Nat. Iles Canaries, vol. 2, pt. 2, Foram., p. 130, pl. 1, figs. 34–35.

Pulvinulina canariensis BRADY, *1884*, Challenger Rept., Zool., vol. 9, p. 692, pl. 103, figs. 8–10.

Globorotalia canariensis GALLOWAY and MORREY, *1929*, Bull. Am. Paleontology, vol. 15, no. 55, p. 25, pl. 3, fig. 11; CUSHMAN, *1929*, Cushman Lab. Foram. Research Contr., vol. 5, pt. 4, p. 101, pl. 14, figs. 14a–c.

This species is common in the Haitian material. It has a known geological range extending from Miocene to Recent and possibly in the "Older Tertiary."

Dimensions of the figured specimens: greatest diameter 0.47 mm.; shorter diameter, 0.40 mm.

GLOBOROTALIA MENARDII (d'Orbigny)
Plate 42, figures 34, 35

Rotalia menardii D'ORBIGNY, *1826*, Annales Sci. Nat. Paris, vol. 7, p. 273 Modeles, no. 10.

Globorotalia menardii, CUSHMAN, *1930*, Florida Geol. Survey Bull. 4, p. 60, pl. 12, figs. 1a–c; COLE and PONTON, *1930*, Florida Geol. Survey Bull. 5, p. 45, pl. 11, figs. 4, 5 (Lower Oligocene, Marianna limestone); CUSHMAN and PONTON, *1932*, Florida Geol. Survey Bull. 9, p. 99; CUSHMAN and CAHILL, *1933*, U. S. Geol. Survey Bull. 175-A, p. 34, pl. 12, figs. 5a–c.

This is one of the most abundant species in the Haitian material. It also occurs in the Marianna limestone, Choctawhatchee and Shoal River formations of Florida and in the Recent deposits.

Dimensions: longer diameter of figure 34, 0.78 mm., and of figure 35, 0.90 mm.

Genus GYROIDINA d'Orbigny, 1826
GYROIDINA LAEVIS d'Orbigny
Plate 43, figures 20a–c, 28

Gyroidina laevis D'ORBIGNY, *1826*, Annales Sci Nat. Paris, vol. 7, p. 278, no. 3; FORNASINI *1898*, Accad. sci. Ist. Bologna Mem., Sez. Sci

Nat., ser. 5, vol. 7, p. 260, fig. 7; GALLOWAY and MORREY, *1929*, Bull. Am. Paleontology vol. 15, no. 55, p. 27, pl. 4, fig. 2.

This species is fairly abundant in the Haitian material. It is known to range from Older Tertiary to Recent.

Dimensions: figure 2; diameter 0.45 mm.; thickness 0.4 mm. Figure 3, diameter 0.63 mm.

GYROIDINA SOLDANII ALTIFORMIS
R. E. and K. C. Stewart
Plate 43, figures 19a–c

Gyroidina soldanii altiformis R. E. and K. C. STEWART, *1930*, Jour. Paleontology, vol. 4, p. 67, pl. 9, fig. 2a–c; CUSHMAN, *1931*, U. S. Nat. Mus. Bull. 104, pt. 8, p. 41, pl. 8, fig. 10a–c; pl. 9, figs. 1a–c.

This variety is common in the Haitian sample. It was first described from the Pliocene (Upper Pico) of California, and later discovered in the Recent deposits of the Atlantic. The Haitian occurrence is the first fossil record of the variety in the Caribbean area, and also the oldest geological appearance. It may have originated here in the vicinity of Haiti and migrated to California by Pliocene time. Diameter of figured specimen, 0.45 mm.

Genus PLANULINA d'Orbigny, 1826
PLANULINA ARIMINENSIS d'Orbigny
Plate 44, figures 7a–c

Planulina ariminensis D'ORBIGNY, *1826*, Annales Sci. Nat. Paris, vol. 7, p. 280, pl. 5, figs. 1–3; CUSHMAN, *1926*, Cushman Lab. Foram. Research Contr., vol. 5, pt. 4, p. 102, pl. 15, figs. 3, 4; —, *1931*, U. S. Nat. Mus. Bull. 104, pt. 8, p. 110.

Planorbulina ariminensis PARKER, JONES and BRADY, *1865*, Annals and Mag. Nat. History. ser. 3, vol. 16, p. 26, pl. 3, fig. 78.

Anomalina ariminensis H. B. BRADY, *1884*, Challenger Rept., Zool., vol. 9, p. 674, pl. 93, figs. 10, 11.

This species is quite common in the Haitian material. The specimens are thin flat forms, on each one of the coil showing on both sides, with limbate sutures and truncate periphery. They do not possess a ventral umbo. Dimensions of the figured specimen: diameter, 0.95 mm., thickness, 0.12, mm.

PLANULINA FOVEOLATA (H. B. Brady)
Plate 44, figures 1a–c

Anomalina faveolata H. B. BRADY, *1884*, Challenger Rept., Zool., vol. 9, p. 674, pl. 94, figs. 1a–c.

Planulina foveolata CUSHMAN, *1931*, U. S. Nat. Mus. Bull. 104, pt. 8, p. 111, pl. 20, figs. 2, 3.

The published description and figures of morphotypes of this species are so variable that it seems proper to include the Haitian specimens here until it is possible to give the species and its several synonyms a thorough vision. Dimensions of the figured specimens: greater diameter 0.65 mm.; thickness, 0.5 mm.

PLANULINA WUELLERSTORFI
(Schwager)
Plate 44, figures 3a–c

Anomalina wuellerstorfi SCHWAGER, *1866*, Novara-Reise, geol. Theil, vol. 2, p. 258, pl. 7, figs. 105, 107.

Truncatulina wuellerstorfi H. B. BRADY, *1884*, Challenger Rept., Zool., vol. 9, p. 662, pl. 93, figs. 8, 9.

Planulina wuellerstorfi CUSHMAN, *1929*, Cushman Lab. Foram. Research Contr., vol. 5, pt. 4, p. 104, pl. 15, fig. 1a; —, *1931*, U. S. Nat. Mus. Bull. 104, pt. 8, p. 110, pl. 19, figs. 5, 6.

Cibicides wuellerstorfi GALLOWAY and MORREY, *1929*, Bull. Am. Paleontology, vol. 15, no. 55, p. 31, pl. 4, figs. 11a–c.

This species is quite common in the Haitian material. The thickness is as variable among these specimens as stated by Cushman for those that he studied. The geologic range extends from "Lower Tertiary" to Recent. Diameter of the figured specimen, 0.7 mm.

Genus SIPHONINA Reuss, 1850
SIPHONINA PULCHRA Cushman
Plate 43, figures 23a–c

Siphonina pulchra CUSHMAN, *1919*, Carnegie Inst. Washington Pub. 291, p. 42, pl. 14, figs. 7a–c; —, 1922, ibid., Pub. 311, p. 49, pl. 7, figs. 11, 12; —, *1926*, ibid., Pub. 344, p. 42; —, *1927*, U. S. Nat. Mus. Proc., vol. 72, art. 20, p. 8, pl. 2, fig. 5; COLE, *1931*, Florida Geol. Survey Bull. 6, p. 51, pl. 4, fig. 2; CUSHMAN, *1931*, U. S. Nat. Mus. Bull, 104, pt. 8, p. 60, pl. 14, figs. 2, 3.

Siphonina reticulata CUSHMAN, (not Czjzek), *1919*, Carnegie Inst. Washington Pub. 291, p. 42.

This species occurs quite frequently in the Haitian sample. Dimensions of the figured specimen: height, 0.46 mm., width 0.49 mm.; thickness, 0.17 mm.

SIPHONINA TENUICARINATA Cushman
Plate 43, figures 22, 29

Siphonina teniucarinata CUSHMAN, *1927*, Jour. Paleontology, vol. 1, p. 166, pl. 26, figs. 11,

12; —, *1927*, U. S. Nat. Mus. Proc., vol. 72, art. 20, p. 6, pl. 4, figs. 1a–c; —, *1929*, Cushman Lab. Foram. Research Contr., vol. 5, p. 100, pl. 14, figs. 9a–c; CORYELL and EMBICK, *1937*, Jour. Paleontology, vol. 11, p. 301, pl. 43, figs. 7a–b.

This species is one of the most distinctly marked amongst the Haitian material. It has been recorded from Upper Eocene and lower Oligocene in Panama, the lower Oligocene, Alazan of Mexico and Lower Miocene, Ditrups bed of Naparima, Trinidad.

The diameters of the figured specimens: figure 5, 0.47 mm.; figure 6, 0.44 mm.

Genus VALVULINERIA Cushman, 1926
VALVULINERIA INAEQUALIS (d'Orbigny)
Plate 43, figures 26a–c

Valvulina inaequalis D'ORBIGNY *1839* (1843), Voyage Am. Merid., vol. 5, pt. 5, p. 48, pl. 7, figs. 10–12.

Valvulineria inaequalis, CUSHMAN, *1927*, Scripps Inst. Oceanography, tech. ser., vol. 1, no. 10, p. 161, pl. 4, figs. 9, 10.

The Haitian occurrence of this species is the first known Caribbean or Atlantic record. Other specimens have been secured from the Pacific area, off southern California and south of Panama.

Dimension of the figured specimen: length, 0.95 mm.; width, 0.57 mm.; thickness, 0.4 mm.

VALVULINERIA COLLIS Coryell and Rivero, n. sp.
Plate 43, figures 24a–c

Test of medium size, slightly longer than wide, dorsal side nearly flat, ventral side with chambers increasing very rapidly in thickness, so that the thickness through the last chamber is nearly two-thirds the length of the test; periphery bluntly keeled, the early part smoothly curved, later more or less lobulated; chambers distinct, few (a maximum of 10 observed), one to one and one-half whorls visible on the dorsal side, the earlier chambers often obscured, only one whorl visible on ventral side, six to seven chambers in last whorl. The first two or three chambers after the proloculum increase rapidly in size; in the last whorl, the height of the chambers (i.e. the dimension parallel to the axis of coiling) remains nearly constant, but the width increases rapidly, and the thickness even more so. The sutures, dorsal and ventral, are curved, very broadly limbate and raised above the surface as thick ridges, at least in the later chambers. The terminal face is a curved plane, appearing progressively more curved as it follows the

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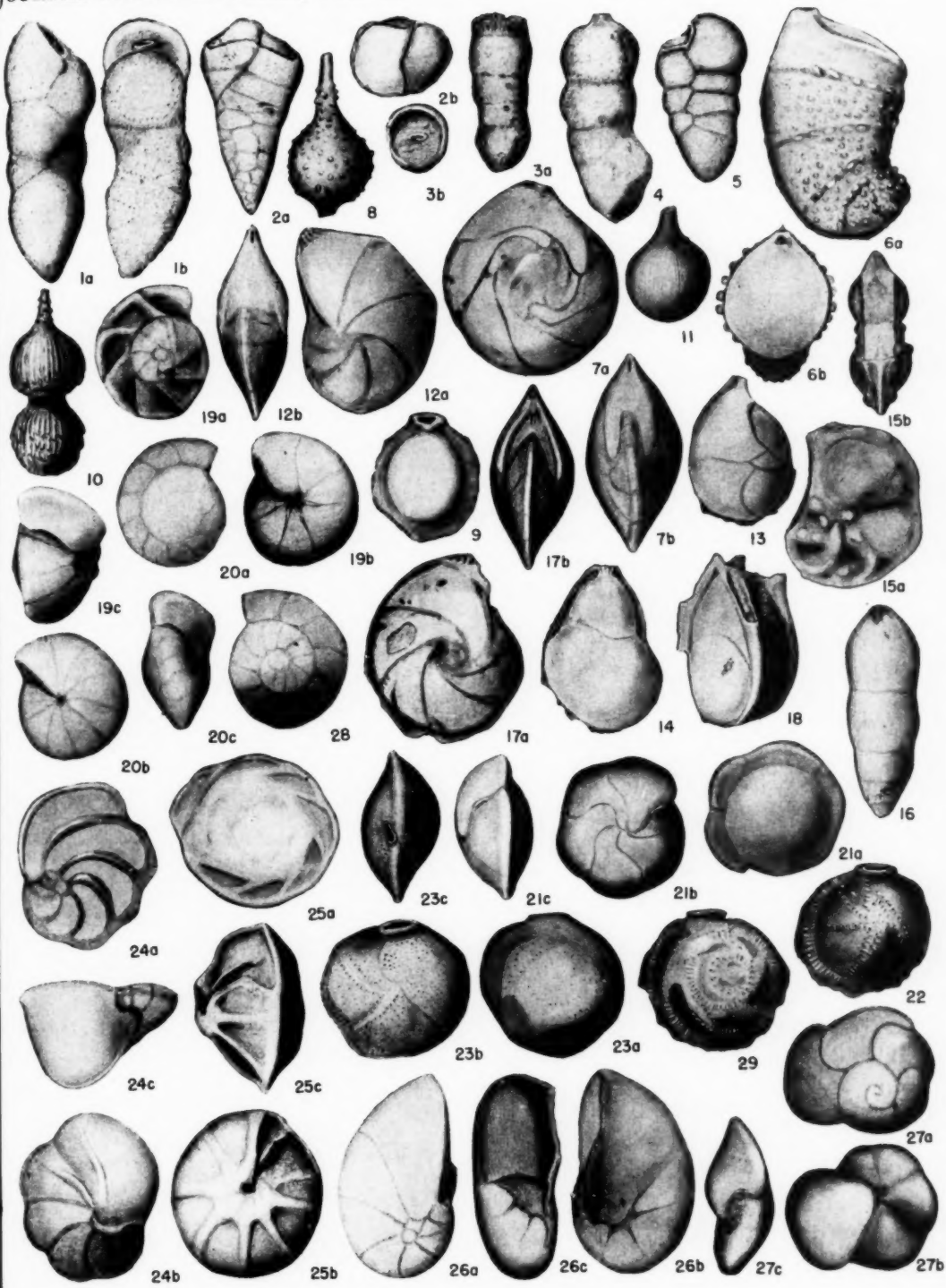
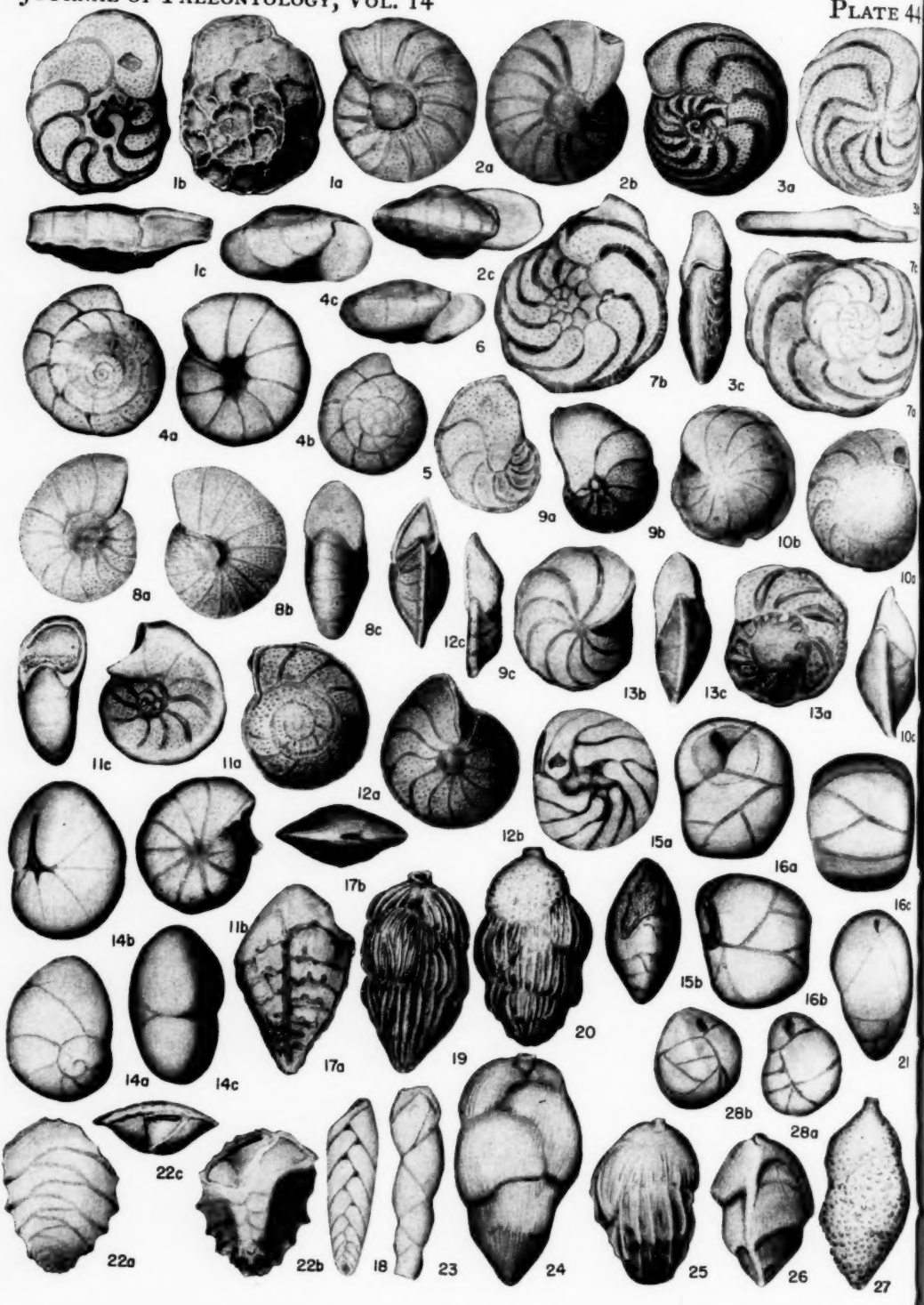
EXPLANATION OF PLATE 43

FIGS. *1a–b—Karreriella subcylindrica* (Nuttall), ×25 (p. 326)
2a–b—Dorothia californica Cushman and Kleinpell, × 45 (p. 325)
3a–b—Listerella nodulosa (Cushman), ×20 (p. 326)
4—Pseudoclavulina mexicana (Cushman), ×35 (p. 325)
5—Karreriella bradyi (Cushman), ×30 (p. 326)
6a–b—Marginulina papillata Coryell and Rivero, n. sp., × 35 (p. 329)
7a–b—Robulus clericii (Fornasini), ×50 (p. 332)
8—Lagenonodosaria schlichti Reuss, ×45 (p. 328)
9—Pyrgo murrhina (Schwager), ×30 (p. 324)
10—Lagenonodosaria spinicosta (d'Orbigny), ×70 (p. 328)
11—Oolina striata d'Orbigny, ×45 (p. 331)
12a–b—Robulus oblongus Coryell and Rivero, n. sp., ×35 (p. 332)
13–14—Lenticulina peregrina (Schwager), ×45 (p. 328)
15a–b—Laticarinina angustata Coryell and Rivero, n. sp., ×35 (p. 333)
16—Nodosaria radicula (Linnaeus), ×15 (p. 331)
17a–b—Robulus limbosus (Reuss), ×35 (p. 332)
18—Robulus deformis (Reuss), ×35 (p. 332)
19a–c—Gyroidina soldanii var. *altispira* R. E. and K. C. Stewart, ×50 (p. 337)
20a–c, 28—Gyroidina laevis d'Orbigny, ×50 (p. 336)
21a–c—Eponides umbonatus (Reuss), ×40 (p. 336)
22, 29—Siphonia tenuicarinata Cushman, (two specimens). ×55 (p. 337)
23a–c—Siphonina pulchra Cushman, ×50 (p. 337)
24a–c—Valvulineria collis Coryell and Rivero, n. sp., ×45 (p. 338)
25a–c—Eponides praecinctus (Karrer), ×40 (p. 336)
26a–c—Valvulineria inaequalis (d'Orbigny) ×45 (p. 338)
27a–c—Globorotalia canariensis (d'Orbigny) ×55 (p. 336)



Coryell and Rivero, Miocene Foraminifera



Coryell and Rivero, Miocene Foraminifera

longer sutural arc of each added chamber. It is bordered in the younger specimens by the strongly raised ridges which will form the suture with the next added chamber; but in the most mature specimen, there is a tendency for this ridge on the ventral side to be formed somewhat back from the septal face and also to die out toward the periphery; this feature is seen in the last two chambers. In addition, the last chamber is "undercut" or steeply truncate from its ridge to the preceding suture, in distinct contrast to the broad curve of the terminal face. The aperture is situated in the ventral umbilicus which is little if at all depressed, hidden by a conspicuous flap that extends back from the terminal face. The wall is distinctly perforate in well-preserved specimens, the sutural ridges consist of clear shell material. Dimensions of figured specimen: length 0.75 mm., width 0.65, thickness 0.5 mm.

Family ASTERIGERINIDAE d'Orbigny, 1839

Genus AMPHISTEGINA d'Orbigny 1826

AMPHISTEGINA ANGULATA (Cushman)

Asterigerina angulata CUSHMAN, *1919*, Carnegie Inst. Washington. Pub. 291, p. 45, pl. 13, fig. 1.

There is a large number of morphotypes of this species from the topotype material from Cercado de Mao, Santa Domingo. They are distinctly species of *Amphistegina*.

AMPHISTEGINA LESSONII d'Orbigny

Amphistegina lessoni D'ORBIGNY, *1826*, Annales Sci. Nat. Paris, vol. 7, p. 304, pl. 17, figs. 1–4.

In the Haitian material there are numerous specimens that can be referred to this species.

Family ORBULINIDAE Schultze, 1854

Genus GLOBIGERINA d'Orbigny, 1826

GLOBIGERINA ALTISPIRA Cushman and Jarvis

Plate 42, figure 31

Globigerina altispira CUSHMAN and JARVIS, *1936*, Cushman Lab. Foram. Research Contr., vol. 12, pt. 1, p. 5, pl. 1, figs. 13, 14.

This species has been described from the Bowden marl of Jamaica, and it is one of common species in the Haitian collection. Diameter of figured specimen, 0.55 mm.

GLOBIGERINA HAITIENSIS Coryell and Rivero, n. sp.

Plate 42, figures 29, 30

The shape of the specimens of this species is somewhat like *G. conglobata*, but it lacks the secondary aperture of the latter. The chambers enlarge too rapidly in the Haitian specimens for them to be classified as *G. in-*

EXPLANATION OF PLATE 44

FIGS. *1a–c—Planulina foveolata* (Brady), ×45 (p. 337)
2a–c— Anomalina nucleata (Sequenza), ×30 (p. 334)
3a–c—Planulina wuellerstorfi (Schwager), ×40 (p. 337)
4a–c, 5, 6. Cibicides robertsonianus haitiensis Coryell and Rivero, n. var., × 40 (p. 335)
7a–c—Planulina ariminensis d'Orbigny, ×30 (p. 337)
8a–c— Anomalina flintii Cushman, ×40 (p. 334)
9a–c—Cibicides concentricus (Cushman), × 45 (p. 334)
10a–c—Cibicides floridanus (Cushman), ×30 (p. 334)
11a–c—Cibicides io Cushman, ×50 (p. 334)
12a–c—Cibicides sinistralis Coryell and Rivero, n. sp., ×40 (p. 335)
13a–c—Cibicides perforatus Coryell and Rivero, n. sp., ×45 (p. 335)
14a–c—Ceratobulimina alazanensis Cushman and Harris, ×30 (p. 342)
15a–c—Cassidulina reflexa Galloway and Wissler, ×75 (p. 342)
16a–c, 28a–c—Cassidulina subglobosa quadrata Cushman and Hughes, ×35, ×50 (p. 342)
17a–c—Bolivina byramensis Cushman, ×100 (p. 341)
18—Bolivina arta Macfadyen, ×70 (p. 341)
19—Uvigerina peregrina Cushman, ×50 (p. 343)
20—Uvigerina pigmea d'Orbigny, ×50 (p. 343)
21—Bulimina affinis d'Orbigny, ×50 (p. 341)
22a–c—Ehrenbergina bradyi Cushman, ×35 (p. 342)
23—Pleurostomella alternans Schwager, ×35 (p. 344)
24—Uvigerina laviculata Coryell and Rivero, n. sp., ×30 (p. 343)
25—Uvigerina beccarii Fornasini, ×40 (p. 342)
26—Angulogerina eximia Cushman and Jarvis, ×35 (p. 342)
27—*Uvigerina senticosa* Cushman, ×35 (p. 343)

flata. The shape does not seem to be as square as that of *G. conglomerata* and the chambers enlarge much more rapidly in the Haitian form than in the latter.

Dimensions: figure 29, diameter, 0. 55 mm.; figure 30, diameter, 0.7 mm.

Genus GLOBIGERINOIDES Cushman, 1927

GLOBIGERINOIDES RUBA (d'Orbigny)

Globigerina ruba D'ORBIGNY, *1839*, in de la Sagra, Hist. Physique Pol. Nat. Cuba, Foram., p. 82, pl. 4, figs. 12–14; CUSHMAN, *1919*, Carnegie Inst. Pub. 291, p. 39; —, *1924*, U. S. Nat. Mus. Bull. 104, pt. 5, p. 15, pl. 3, figs. 4–7.

This species occurs quite frequently in the Haitian material. It has also been found in the Bowden formation in Jamaica.

GLOBIGERINOIDES SACCULIFERA (H. B. Brady)

Plate 42, figures 24, 25, 32

Globigerina helicina CARPENTER, *1862*, (not d'Orbigny), Introduction Foraminifera, pl. 12, fig. 11.

Globigerina sacculifera H. B. BRADY, *1877*, Geol. Mag., dec. 2, vol. 4, p. 535; —, Challenger Rept., Zool., vol. 9, p. 604, pl. 80, figs. 11–17, pl. 82, fig. 4; CUSHMAN, *1918*, Florida Geol. Survey, Bull. 676, p. 57, pl. 13, fig. 2 (Choctawhatchee Marl, Florida); —, *1924*, U. S. Nat. Mus. Bull. 104, pt. 5, p. 21, pl. 4, figs. 1–6; —, *1919*, Carnegie Inst. Washington, Pub. 291, p. 39.

Globigerinoides sacculifera CUSHMAN and JARVIS, *1930*, Jour. Paleontology, vol. 4, no. 4, p. 366, pl. 34, fig. 4.

Specimens of this species are very abundant in the Haitian material. The last chambers are not quite so irregular as that figured by Cushman and Jarvis. The species also occurs in the Miocene (Bowden Marl) of Jamaica.

GLOBIGERINOIDES TRILOBA (Reuss)

Globigerina triloba REUSS, *1850*, Akad. Wiss. Wien Math.-Naturwiss. Kl., Denkschr., vol. 1, p. 374, pl. 47, figs. 11a–e; CUSHMAN, *1924*, U. S. Nat. Mus. Bull. 104, pt. 5, p. 7.

The specimens that are assigned to this species differ from the figured specimen of Reuss in that the number of supplementary apertures appears to be greater in the Haitian forms. The extra aperture is present in the figures published by Reuss but does not occur in those published by Rhumbler. The latter have been erroneously reproduced for *Globigerina triloba* Reuss.

This species is common in the Haitian sample.

Genus ORBULINA d'Orbigny, 1839

ORBULINA UNIVERSA d'Orbigny

Orbulina universa D'ORBIGNY, *1839*, in Barker, Webb and Berthelot, Hist. Nat. Illes Canaries, vol. 2, pt. 2, Foram., p. 123, pl. 1, fig. 1; —, *1839*, in de la Sagra, Hist. Physique Pol. Nat. Cuba, Foram., p. 3, pl. 1, fig. 1; CUSHMAN, *1918*, U. S. Geol. Surv. Bull. 676, p. 12, pl. 3, fig. 3; —, *1919*, Carnegie Inst. Washington, Pub. 291, p. 40; —, 1924, U. S. Nat. Mus. Bull. 104, pt. 5, p. 28, pl. 5, figs. 2–9; —, *1930*, Florida Geol. Survey Bull. 4, p. 59; COLE, *1931*, Florida Geol. Survey Bull. 6, p. 55; CUSHMAN and JARVIS, *1930*, Jour. Paleontology, vol. 4, p. 367.

This species is one of the dominant forms in the Haitian material. It has been recorded from the Lias to the present and occurs commonly in the Miocene of Santa Domingo, the Canal Zone, Florida (Choctawhatchee formation) and Jamaica (Buff Bay), also in the Pliocene of Florida (Waccaman and Caloosahatchee).

Family PEGIDIIDAE Heron-Allen and Earland, 1928

Genus SPHAEROIDINELLA Cushman, 1927

SPHAEROIDINELLA DEHISCENS (Parker and Jones)

Sphaeroidina dehiscens PARKER and JONES, *1865*, Philos. Trans., vol. 155, p. 369, pl. 19, figs. 5a–c; BRADY, H. B., *1884*, Challenger Rept., Zool., vol. 9, p. 621, pl. 84, figs. 8–11; CUSHMAN, *1924*, U. S. Nat. Mus. Bull. 104, pt. 5, p. 38, pl. 7, figs. 7, 8, pl. 8, figs. 1, 2.

Sphaeroidinella dehiscens CUSHMAN and JARVIS, *1930*, Jour. Paleontology, vol. 4, no. 4, p. 367, pl. 34, figs. 6, 7.

Globigerina seminulina SCHWAGER, *1866*, Novara-Reise, geol. Theil, vol. 2, p. 256, pl. 7, fig. 112.

This species is abundant in the Haitian material. It is a pelagic form and recorded off Brazil just south of the equator to latitude 40° north. It is recorded from the Caribbean sea, and also from a large number of the Albatross stations. The specimens occur at depths ranging from 100 to 2501 fathoms, and at temperatures varying from 37.3 to 46.3 degrees F. Average dimension of the Haitian specimens, 0.6 mm.

Family HETEROHELICIDAE
Cushman, 1927
Genus BOLIVINA d'Orbigny, 1839
BOLIVINA ARTA Macfadyen
Plate 44, figure 18

Bolivina arta MACFADYEN, *1930* (1931), Geol. Survey Egypt, p. 58, pl. 4, figs. 21a–b; CUSHMAN, *1937*, Cushman Lab. Foram. Research Spec. Pub. No. 9, p. 79, pl. 9, figs. 23–26.

The Haitian specimen closely resembles Macfadyen's species, even though it is known only from the Miocene of Egypt. Length of the figured specimen, 0.4 mm.

BOLIVINA BYRAMENSIS (Cushman)
Plate 44, figure 17a–c

Bolivina caelata byramensis CUSHMAN, *1923*, U. S. Geol. Survey Prof. Paper 133, p. 19, pl. 1, fig. 9.

Bolivina byramensis CUSHMAN, *1937*, Cushman Lab. Foram. Research Spec. Pub. no. 9, p. 69, pl. 8, figs. 18–20.

In the Haitian collection are several specimens that possess subreticulate ornamentation, that have been referred to this species.

Dimension of the figured specimens: length, 0.3 mm.; width, 0.19 mm.; thickness, 0.08 mm.

BOLIVINA OBSCURANTA Cushman

Bolivina obscuranta CUSHMAN, *1936*, Cushman Lab. Foram. Research Spec. Pub. no. 6, p. 53, pl. 7, figs. 20a–b; —, *1937*, ibid., Spec. Pub. no. 9, p. 93, pl. 12, figs. 9a, 9b.

This species, described from the Miocene of the adjoining Dominican Republic, is common in the Haitian collection. It is represented by both the microspheric and megalospheric forms.

PLECTOFRONDICULARIA Liebus, 1902
PLECTOFRONDICULARIA VAUGHNI
Cushman
Plate 42, figure 28

Plectofrondicularia vaughni CUSHMAN, *1927*, Cushman Lab., Foram. Research, vol. 3, pt. 2, no. 41, p. 112, pl. 23, fig. 3; NUTTALL, *1932*, Jour. Paleontology, vol. 6, no. 1, p. 112, pl. 23, fig. 3; CORYELL and EMBICH, *1937*, Jour. Paleontology, vol. 11, no. 4, p. 303, pl. 42, fig. 15.

The Haitian specimen show slight indication of a biserial character in the early chambers and a little variation in the alignment of the apertural positions.

Length of the figured specimen 1.0 mm.

Family BULIMINIDAE Jones, 1876
Genus BULIMINA d'Orbigny, 1826
BULIMINA AFFINIS d'Orbigny
Plate 44, figure 21

Bulimina affinis D'ORBIGNY, *1839* (1840), de la Sagra Hist. Phys. Nat. Cuba, Foram., p. 105, pl. 2, figs. 25, 26.

The test is of medium size for the genus, very gently tapering with about four whorls visible, the last whorl making up about two-thirds of the test; suture not depressed; wall smooth and finely perforate; aperture is narrow.

Length of figured specimen, 0.48 mm., and diameter, 0.29 mm.

BULIMINA INFLATA Seguenza

Bulimina inflata SEGUENZA, *1862*, Acad. gioenia sci. nat. Atti., ser. 2, vol. 13, p. 109, pl. 1, fig. 10; GALLOWAY and MORREY, *1929*, Bull. Am. Paleontology, vol. 15, no. 55, p. 37, pl. 5, fig. 13; CUSHMAN, *1929*, Cushman Lab. Foram. Research Contr., vol. 5, pt. 4, p. 94, pl. 13, fig. 31; CUSHMAN and JARVIS, *1930*, Jour. Paleontology, vol. 4, pt. 4, p. 362, pl. 33, fig. 5; CUSHMAN, *1930*, Florida Geol. Survey Bull. 4, p. 43, pl. 8, figs. 6a–b; CUSHMAN and CAHILL, *1933*, U. S. Geol. Survey Prof. Paper 175-A, p. 24, pl. 8, fig. 11; CORYELL and EMBICH, *1937*, Jour. Paleontology, vol. 11, no. 4, p. 304, pl. 42, fig. 19.

This well known species occurs quite frequently in the Haitian collection.

BULIMINA MARGINATA d'Orbigny

Bulimina marginata D'ORBIGNY, *1826*, Annales Sci. Nat., Paris, vol. 7, p. 269, pl. 12, figs. 10–12; CUSHMAN, *1922*, U. S. Nat. Mus. Bull. 104, pt. 3, p. 91, pl. 21, figs. 4, 5; APPLIN, ELLISOR and KNIKER, *1925*, Am. Assoc. Petroleum Geologists Bull., vol. 9, no. 1, p. 98, pl. 3, fig. 4 (Subsurface marine Miocene, Gulf Coast); COLE, *1931*, Florida Geol. Survey Bull., 6, p. 39 (Pliocene, Florida); CUSHMAN and PONTON, *1932*, Florida Geol. Survey Bull. 9, p. 77, pl. 11, fig. 12.

This species is rare in the Haitian locality.

Genus REUSSELLA Galloway, 1933
REUSSELLA SPINULOSA GLABRATA
(Cushman)

Verneuilina spinulosa glabrata CUSHMAN, *1922*, U. S. Geol. Survey Prof. Paper 129-e, p. 92; —, *1923*, ibid., Paper 133, p. 21.

Reussia spinulosa CUSHMAN and PONTON (part), *1932*, Florida Geol. Survey Bull. 9, p. 84, pl. 12, fig. 15. (not figs. 14, 16).

The Haitian material contains a few

forms that closely resemble Reuss's smooth variety of the species.

Family CASSIDULINIDAE
d'Orbigny, 1839
Genus CASSIDULINA d'Orbigny, 1826
CASSIDULINA REFLEXA Galloway
and Wissler
Plate 44, figures 15a–c

Cassidulina reflexa GALLOWAY and WISSLER, *1927*, Jour. Paleontology, vol. 1, no. 1, p. 80, pl. 12, fig. 13.

The Haitian specimens appear to check very closely with the Pleistocene types. The former are not quite so well preserved.

Dimensions of the figured specimen: Length 0.32 mm., width, 0.28 mm., thickness 0.16 mm.

CASSIDULINA SUBGLOBOSA QUADRATA
Cushman and Hughes
Plate 44, figures 16a–c, 28a–c

Cassidulina subglobosa quadrata CUSHMAN and HUGHES, *1925*, Cushman Lab. Foram. Research Contr., vol. 1, no. 1, p. 15, pl. 2, figs. 7a–c.

The figures of the type specimen from the Pleistocene of Lomita Quarry, Palos Verdes Hills, Los Angeles County, California show a somewhat different arrangement of chambers in side view in comparing it with the Haitian specimens, however, it seems proper at this time to include the latter in the same species.

Dimensions: Length of the large specimen (figs. 5a–c), 0.7 mm.; of the small specimen (fig. 10a, b), 0.34 mm.

Genus CERATOBULIMINA Toula, 1915
CERATOBULIMINA ALAZANENSIS
Cushman and Harris
Plate 44, figure 14a–c

Ceratobulimina alazanensis CUSHMAN and HARRIS, *1927*, Cushman Lab. Foram. Research Contr., vol. 3, pt. 4, p. 174, pl. 29, figs. 5a–c; pl. 30, figs. 3–5; CORYELL and EMBICH, *1937*, Jour. Paleontology, vol. 11, no. 4, p. 302, pl. 43, figs. 8a–b.

The Haitian specimens seem to be somewhat more round and the aperture slightly more elongate than the type. The species has formerly been identified from Upper Eocene to Lower Oligocene, however, the Haitian forms appear to belong here.

Dimension of the figured specimen: length, 0.81 mm.; width, 0.56 mm.; thickness 0.5 mm.

Genus EHRENBERGINA Reuss, 1850
EHRENBERGINA BRADYI Cushman
Plate 44, figures 22a–c

Ehrenbergina serrata H. B. BRADY (part) (not Reuss), *1884*, Challenger Rept., Zool., vol. 9, pl. 55, figs. 2, 3, 5.
Ehrenbergina bradyi CUSHMAN, *1922*, U. S. Nat. Mus. Bull. 104, pt. 3, p. 134, pl. 26, fig. 5; —, *1927*, U. S. Nat. Mus. Proc., vol. 70, art. 16, p. 5, pl. 2, fig. 1a–c; —, *1927*, Scripps Inst. Oceanography Bull., tech. ser., vol. 1, no. 10, p. 169, pl. 6, fig. 8.

The Haitian specimen is referred to this species although it is less spinose, appears somewhat more compressed and the ventral furrow not so well developed.

Dimensions: length 0.7 mm., width 0.45 mm., thickness, 0.3 mm.

EHRENBERGINA SPINOSISSIMA
Cushman and Jarvis

Ehrenbergina spinosissima CUSHMAN and JARVIS, *1936*, Cushman Lab. Foram. Research Contr., vol. 12, pt. 1, p. 5, pl. 1, figs. 15, 16.

This species occurs quite frequently in the Haitian material. The spines are not so well developed as in the type from the Bowden Marl one-half mile east of Bluff Bay Jamaica.

Family UVIGERINIDAE Galloway
and Wissler, 1927
Genus ANGULOGERINA Cushman, 1927
ANGULOGERINA EXIMIA Cushman
and Jarvis
Plate 44, figure 26

Angulogerina eximia CUSHMAN and JARVIS, *1936*, Cushman Lab. Foram. Research, Contr., vol. 12, pt. 1, p. 3, pl. 1, figs. 11, 12.

The Haitian specimens are slightly more finely striated than those figured by Cushman and Jarvis. Several of the former are somewhat more slender than the type figures of the species. *Angulogerina eximia* has been recorded from the Bowden Marl, ½ mile east of Buff Bay, Jamaica.

Length of the figured specimen, 0.72 mm.

Genus UVIGERINA d'Orbigny, 1826
UVIGERINA BECCARII Fornasini
Plate 44, figure 25

Uvigerina beccarii FORNASINI, *1898*, Accad. sci. Ist. Bologna, Rendi. Sess., n. s., vol. 2, p. 14,

pl. 1, fig. 5. (Pliocene); GALLOWAY and MORREY, *1929*, Bull. Am. Paleontology, vol. 15, no. 55, p. 38, pl. 6, fig. 2; CUSHMAN, *1929*, Cushman Lab. Foram. Research Contr., vol. 5, pt. 4, p. 95, pl. 13, fig. 37.

The Haitian specimens are very much like the morphotypes of this species in having coarse and fine striae. The apertural depression in the former does not extend so distinctly to the base of the chamber as has been described in some Ecuador forms.

Length of figured specimen, 0.7 mm.

UVIGERINA PEREGRINA Cushman
Plate 44, figure 19

Uvigerina peregrina CUSHMAN, *1923*, U. S. Nat. Mus. Bull. 104, pt. 4, p. 166, pl. 42, figs. 7–10; CUSHMAN, *1927*, Scripps Inst. Oceanography Bull., tech. ser., vol. 1, no. 10, p. 158, pl. 3, fig. 13; GALLOWAY and WISSLER, *1927*, Jour. Paleontology vol. 1, no. 1, p. 76, pl. 12, fig. 1, 2; CUSHMAN, STEWART and STEWART, *1930*, San Diego Soc. Nat. History Trans., vol. 6, no. 2, p. 69, pl. 5, fig. 11; CUSHMAN, *1932*, Florida Geol. Survey Bull. 9, p. 85.

Uvigerina pygmaea FLINT (not U. pigmea d'Orbigny), *1899*, U. S. Nat. Mus. Rept., *1897*, p. 320, pl. 68, fig. 2.

Uvigerina cf *pigmea* CUSHMAN, *1930*, Florida Geol. Survey Bull. 4, p. 49, pl. 9, fig. 3–6.

In the Haitian collection occur several specimens that closely resemble the forms assigned to this species. Length of the figured specimen, 0.7 mm.

UVIGERINA PIGMEA d'Orbigny
Plate 44, figure 20

Uvigerina pigmea D'ORBIGNY, *1826*, Annales Sci. Nat. Paris, vol. 7, p. 269, pl. 12, fig. 8, 9; Modeles, no. 67 (Pliocene, near Siena, Italy); CUSHMAN, *1930*, Cushman Lab. Foram. Research Contr., vol. 6, pt. 3, p. 62, pl. 9, figs. 14–20.

Uvigerina cf *pigmea* CUSHMAN and CAHILL, *1933*, U. S. Geol. Survey Prof. Paper 175-A, p. 27.

The Haitian specimen resembles the form and ornamentation of d'Orbigny's figures and the morphotypes.

Length of the figured specimen, 0.7 mm.

UVIGERINA LAVICULATA Coryell and Rivero, n. sp.
Plate 44, figure 24

This species is ornamented only with numerous very fine longitudinal striae that cover the exposed surface of each chamber and thus differs from *Uvigerina beccari* which has larger costa intercalated between groups of smaller ones. The Haitian specimen is also more pointed on the initial end and longer than *U. beccari*. The apertural neck is set in a depression; the later chambers are distinctly inflated with depressed sutures.

Length of the figured specimen, 1.25 mm.

UVIGERINA QUADRATA Coryell and Rivero, n. sp.
Plate 42, figure 27

In the Haitian collection occurs a smooth uvigerine form, with the last chamber showing a tendency to become triangular, the angles very much rounded. The greatest diameter of the test is near the mid-length; the chambers very much less bulbous than those of *Uvigerina canariensis*. Length of figured specimen, 0.85 mm.

UVIGERINA SENTICOSA Cushman, 1927
Plate 44, figure 27

Uvigerina senticosa CUSHMAN, *1927*, Scripps Inst. Oceanography Bull., tech. ser., vol. 1, no. 10, p. 159, pl. 3, fig. 14.

The Haitian specimens have been referred to Cushman's species from which there is slight differences in prominence of the ornamentation. This species is rather rare in the Haitian material. Length of the figured specimen, 0.65 mm.

Family PLEUROSTOMELLIDAE Reuss, 1860

Genus NODOSARELLA Rzehak, 1885

NODOSARELLA PAUCISTRIATA Galloway and Morrey
Plate 42, figures 21–23

Nodosarella paucistriata GALLOWAY and MORREY, *1929*, Bull. Am. Paleontology, vol. 15, no. 55, p. 42, pl. 6, figs. 12 a-b.

Ellipsonodorsaria verneuili paucistriata CUSHMAN, *1929*, Cushman Lab. Foram. Research Contr., vol. 15, pt. 4, p. 97, pl. 14, figs. 4, 5.

Nodosaria intermittens NUTTALL (not Roemer) *1928*, Geol. Soc. Quart. Jour., vol. 84, p. 82, pl. 4, fig. 17.

This species is very common in the Haitian material. It is recorded from Ecuador and Trinidad. The specimens show some variation in size of the test and enlargement of chambers. Length of the figured speci-

mens: figure 21, 1.4 mm.; figure 22, 1.35 mm., figure 23, 1.3 mm.

NODOSARELLA VERNEUILI d'Orbigny
Plate 42, figures 18–20, 26

Dentalina verneuili D'ORBIGNY, *1846*, Foram. Foss. Bassin Tertiaire, Vienne, p. 48, pl. 2, figs. 7, 8.
Nodosaria verneuili, NUTTALL, *1928*, Geol. Soc. Quart. Jour., vol. 84, p. 81, pl. 4, figs. 14, 15.
Nodosaria crassielegans NUTTALL, 1. c. p. 80, pl. 4, figs. 6, 7 (Fide Cushman).
Nodosarella camerani GALLOWAY and MORREY, (not Dervieux according to Cushman), *1929*, Bull. Am. Paleontology, vol. 15, no. 55, p. 41, pl. 6, figs. 9–11.
Ellipsonodosaria verneuili, CUSHMAN, *1929*, Cushman Lab. Foram. Research Contr., vol. 5, pt. 4, p. 96, pl. 14, figs. 1–3.

In following the type selected it seems proper to use *Nodosarella verneuili* for the Haitian specimens. This species occurs quite frequently in the material from Haiti. Lengths of the figured specimens: figure 18, 2.3 mm.; figure 19, 1.6 mm.; figure 20, 1.8 mm.; figure 26, 1.4 mm.

Genus PLEUROSTOMELLA Reuss, 1860
PLEUROSTOMELLA ALTERNANS Schwager
Plate 44, figure 23

Pleurostomella alternans SCHWAGER, *1866*, Novara-Reise, geol. Theil, vol. 2, p. 238, pl. 6, figs. 79, 80; GALLOWAY and MORREY, *1929*, Bull. Am. Paleontology, vol. 15, no. 55, p. 40, pl. 6. figs. 7, 8; CUSHMAN, *1929*, Cushman Lab. Foram. Research Contr., vol. 5, pt. 4, p. 96, pl. 13, figs. 42, 43.

This species is apparently rare in the Haitian Miocene. It has been recorded from the later Tertiary of Ecuador, Venezuela and Trinidad. Length of the figured specimen, 0.9 mm.

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MICROSCOPIC PELMATOZOA: PART 1, ONTOGENY OF THE BLASTOIDEA[1]

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ABSTRACT—The first completely known larval stages of Paleozoic pelmatozoans, as represented by early growth sequences in two genera of late Mississippian blastoids, *Mesoblastus* and *Pentremites*, are here described. Four arbitrary larval stages are discussed in detail for both *Mesoblastus glaber* (M. and W.) and *Pentremites princetonensis* Ulrich, the processes involved in blastoid metamorphosis are outlined, and a series of early post-larval specimens of *M. glaber* is described.

INTRODUCTION

THE LIFE history of modern crinoids has become well known through elaborate zoological studies of both comatulids and pentacrinids. Thus the developmental stages of the Paleozoic members of the class may at least be inferred, but to date there has been little or no direct *paleontological* information regarding the life history of any of the pelmatozoans. This has been particularly unfortunate since the cystoids and blastoids, being extinct, of course cannot be studied zoologically. The degree of this previous lack of information has been pretty well evaluated by Twenhofel and Shrock who flatly state (p. 171), "Nothing is known of the ontogeny of the Blastoidea."

Careful micropaleontological examination of large suites of early Chester sediments [Renault-Shetlerville] from southern Illinois has, however, in the past decade, yielded many microscopic blastoids and crinoids, the majority of the specimens, numbering approximately 6000 individuals, belonging to the former class. These specimens show, practically completely, the entire sequence of the early growth stages for species of both *Pentremites* and *Mesoblastus*. Inasmuch as the main steps are essentially the same for both of these relatively dissimilar (in ephebic expression) genera, the growth stages are apparently characteristic of the class rather than of any one genus.

The smallest specimens, which can be recognized definitely as such, have a maximum dimension of from 0.09 to 0.14 mm. The average increase in major dimension from the first known stage to adult size is not less than as one to 50. Within this great size range all intermediate stages are known.

Although the problem of microscopic blastoids can scarcely be divorced from that of microscopic crinoids, a complete discussion of the many issues involved, the manifold problems which have been raised, and the many possible relationships which suggest themselves all are reserved for treatment in a subsequent paper. The decision to handle the subject by issuing a preliminary descriptive paper with not much theoretical discussion has been influenced as much by the fact that so many paleontologists have seen and expressed great interest in the material, as by the difficulties and the time involved in adequately handling all of the theoretical problems.

Although microscopic crinoids receive scant direct attention in this paper, they have nevertheless been taken into thorough consideration in its preparation. Accordingly the list of references accompanying this article will be found relatively complete by those who wish to explore further the general problem of microscopic pelmatozoans and their possible interrelationships.

The difficulties of properly placing a larval blastoid in the supposed ephebic growth stage to which it belongs will be apparent to all micropaleontologists. Such an identification, which may be difficult enough to handle in those paleontological groups which do not pass through a metamorphosis, becomes doubly doubtful in such a group as the blastoidea with both larval and post-larval expressions. Therefore the specific reference of our larval material to either *M. glaber* or *P. princetonensis* must not be

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regarded as beyond question, although the generic assignments are definite.

MATERIALS AND METHODS OF STUDY

All of the specimens on which this paper is based are deposited in Walker Museum, University of Chicago. They will be catalogued and assigned individual or group numbers after further work has more definitely established the limits and usefulness of certain of the preliminary categories.

All of the material was sorted from the Renault, and "Renault-Shetlerville," Chester sediments of southern Illinois. The most fertile samples came from the so-called "Shetlerville Bed" of the Renault formation in the Melcher Hills just north of Shetlerville, Illinois. More precise locations will be listed in a subsequent paper.

In order to work with the larval blastoids to the greatest advantage, and especially in order to identify the plate systems in the earliest stages, it is necessary that the specimens be stained. After considerable experimentation it was found that the best stain for the purpose is methylene blue. The specimens are dried after having been immersed in a very weak solution with the result that the sutures show up with reasonable clarity, and, with proper handling, the surface of the plates is not too strongly stained.

ACKNOWLEDGMENTS

Our thanks are due Dr. M. M. Leighton, Chief of the Illinois Geological Survey, for putting at our disposal many of the Chester samples on which this work is based, and to members of his staff, especially Mr. L. E. Workman and Mr. J. E. Lamar, who did much of the collecting.

In addition to Mr. Geis who did most of the sorting and examination of material prior to 1934, many other graduate students have during the past 10 years contributed in varying degree to the success of this project. Inasmuch as space does not permit mention of all who have rendered assistance, especially in enlarging our collection, we will not cite any of these valued helpers specifically. We cannot refrain, however, from expressing appreciation of the services of Dr. L. L. Sloss, now of the Montana School of Mines and Louise Barton Freeman, of the Kentucky Geological Survey, who have given so much aid in collecting, sorting, and arranging the material for study.

ONTOGENY OF MESOBLASTUS GLABER (Meek and Worthen)

FIRST STAGE

Arrangements of the plates in the globular blastoid larva at the first recognizable stage cannot be certainly determined from the specimens available, but from the fragmentary evidence they afford, it seems probable that there is no significant difference except one of size between this earliest stage and the one, which, for convenience, is labeled second stage. Accordingly, a discussion of the plates is deferred to the description of the second larval stage.

A few stem-bearing specimens of the first stage have been found, the top stem segment being comparatively large, the second segment materially smaller. Such individuals have a deceptive appearance, as though the calyx itself were elongated. The base in such a larva is marked by a facet or pit, closely resembling that occurring on the older forms.

It is evident that this first known stalked larva with firmly articulated plates has already passed through a more or less complex series of growth changes before the secretion of the test. Possibly comparisons with the early stages of development in both the free and fixed larvae of one or another of the modern echinoderms should be made, but such hypothetical discussions are for the most part reserved for another paper. We may at once, however, discard the speculative comparison between the *Pentremite* larva and that of *Antedon* in the sense suggested by Miss Smith, for she naturally, though mistakenly, thought that the early *post-larval* individuals in her collection were the first to secrete a preservable test.

SECOND STAGE

In its second stage the larva of *Mesoblastus* is a spherical body ranging up to 0.2 mm. in diameter, and consisting of 13 closely articulated, smooth plates, arranged in three series or rings.

Basal plates.—The three proximal or aboral plates, which are retained through-

out the rest of larval growth and later expand into the basals of the adult, differ in no essential feature from the same plates in later stages, except that the small basal is more nearly triangular than quadrate, and is truncate at its top. In this species it apparently lies in the position of the right posterior interray (as viewed from below). The other basals are larger but also typically triangular. The belief of Hambach, that in the embryonic state the blastoid base is composed of five equal plates, later reduced to three by fusion of two pairs, is clearly inaccurate, at least for this species. Either the primitive ancestor of *Mesoblastus* (and, by inference, of all of the blastoids) had a basal series of three plates, rather than five as rather commonly postulated, or, far less likely, the pentamerous stage was eliminated from the ontogeny of the genus before Chester time. The basal plates, composing about a third of the calyx, encircle proximally a rather large facet which is, of course, obscured in a very few of the better preserved specimens by the upper stem plate.

Radial plates.—The second or ambital series is composed of five hexagonal or pentagonal plates, which differ markedly from the radials of the later larval stages, and still more markedly from the radials of the adult. They are, however, the same plates, later modified by differential accretion. Employing an aboral orientation, the anterior, the right anterior and the left posterior radials are pentagonal, the latter more produced distally, than the other two, which are obtuse distally. The left anterior and right posterior radials are hexagonal. The radials are relatively very large and nearly equidimensional, thus vaguely resembling the radials of the Ordovician cystoid, *Cryptocrinus*. The radials occupy about a third of the length of the calyx.

Distal plates.—The third series, for convenience, called "distals" in this preliminary discussion, is composed of five plates which are truly larval structures, inasmuch as they are resorbed (or shed) at the metamorphosis of the individual. Their outline is in general quadrate at this stage, the two lower sides short and meeting at an obtuse angle, the upper margins long and meeting at an acute angle or a bluntly rounded end. The sutures between the distal plates are stronger in most specimens than those on the abactinal surface, and possibly constitute food grooves. Each groove terminates proximally at the upper peak of the radials without modifying its outline.

Neither mouth nor anus is observable as an enlarged portion of the sutures or as a separate pore, but possibly their positions may be inferred from the eccentricities of the suture junctions on the oral surface. The mouth is probably located at the tip of the smaller right anterior distal (oral view), the anus at the tips of the two distals opposite. The suture between the two points is commonly the strongest of the entire calyx. There is considerable variation in the oral junctions of the food grooves, though the situation described is the most common. The fact of variation may, however, vitiate any speculation as to the positions of the mouth or anus.

There is no indication either of true arms or of pinnules at this stage, though arms are present on larger larvae, and pinnules almost certainly appear early in post larval development with the formation of the lancet plates. True deltoids first are seen as oral crests in the post larva, well after the distals have disappeared.

In shape, and in number and arrangement of its plates, this early larva is somewhat similar to the aporitan cystoid, *Cryptocrinus*, of the Russian Ordovician, and the resemblance is not entirely lost until the end of larval development. Only the small accessory plates of the mouth and anus are lacking in the young blastoid. Whether the resemblance is fortuitous or significant is, of course, debatable. Certainly the latter hypothesis is at variance with the generally accepted belief that the Eublastoidea developed from some diploporitan cystoid ancestor, through the Protoblastoidea as intermediate forms. The presence in the larva of these distal plates, which are so inessential to the economy of the adult blastoid that they are resorbed (or shed) rather than continued on as deltoids, a simpler and, *a priori* an apparently more feasible disposition of them, would, however, seem ample evidence of their essential occurrence in the adult of some primitive pre-blastoid ancestor.

THIRD STAGE

The third stage in larval development shows an increase in size up to 0.3 mm. length and 0.26 mm. width, and an increase in the relative areas of the basal and distal series at the expense of the radials. As the basals elongate and lose their convexity, the outline of the calyx becomes essentially ovate. terior radial. As the aboral pole becomes conical, the outer edges of the upper margins of the basals are very slightly extended in the "plane" of the cone. The undulating keel thus formed lies at the greatest transverse diameter of the test, and the radials and distals form a smooth hemisphere of slightly smaller diameter resting within it.

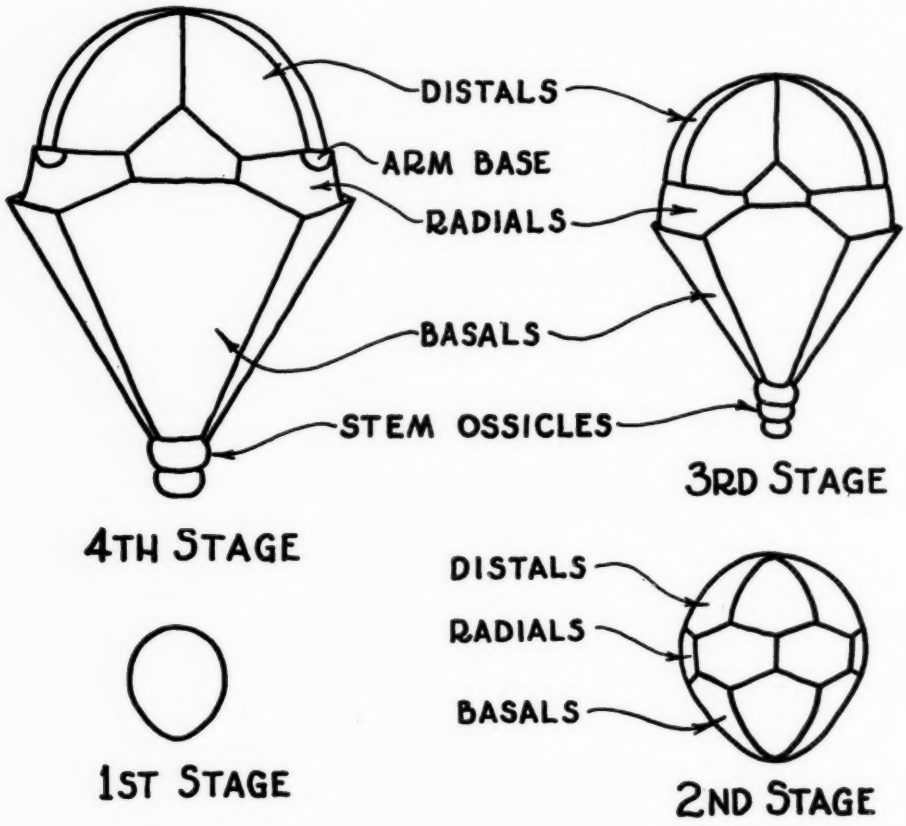

FIG. 1.—Stages in the larval development of *Mesoblastus glaber* (M. and W.), shown diagrammatically.

As oriented in basal plan, the anterior and right anterior radials are essentially rectangular, a shape modified in the right posterior and left anterior radials by upward sloping contacts with the lateral margins of the pentagonal basal. The left posterior radial is flat ventrally and acuminate dorsally, where it invades the oral hemisphere. The distals are essentially triangular except as two of them are modified by the left pos-

The radials do not encroach upon this basal cone until the early post larval stages.

FOURTH STAGE

At the fourth stage (0.4 mm. length and 0.3 mm. transverse diameter) the basals constitute nearly or quite half of the entire calyx. Growth lines are prominent on the basals of some individuals, those paralleling the upper margins being most evident, and

indicating that the most important additions are made distally. On many specimens the keel is prominent, though varying in strength among the individuals, and on different parts of the ambitus on a single upper sutures, are slightly swollen at mid-length, and two of them, the right anterior and left posterior (oral view) bear, at the ends of the food grooves, shallow semilunar depressions or pits with slightly elevated

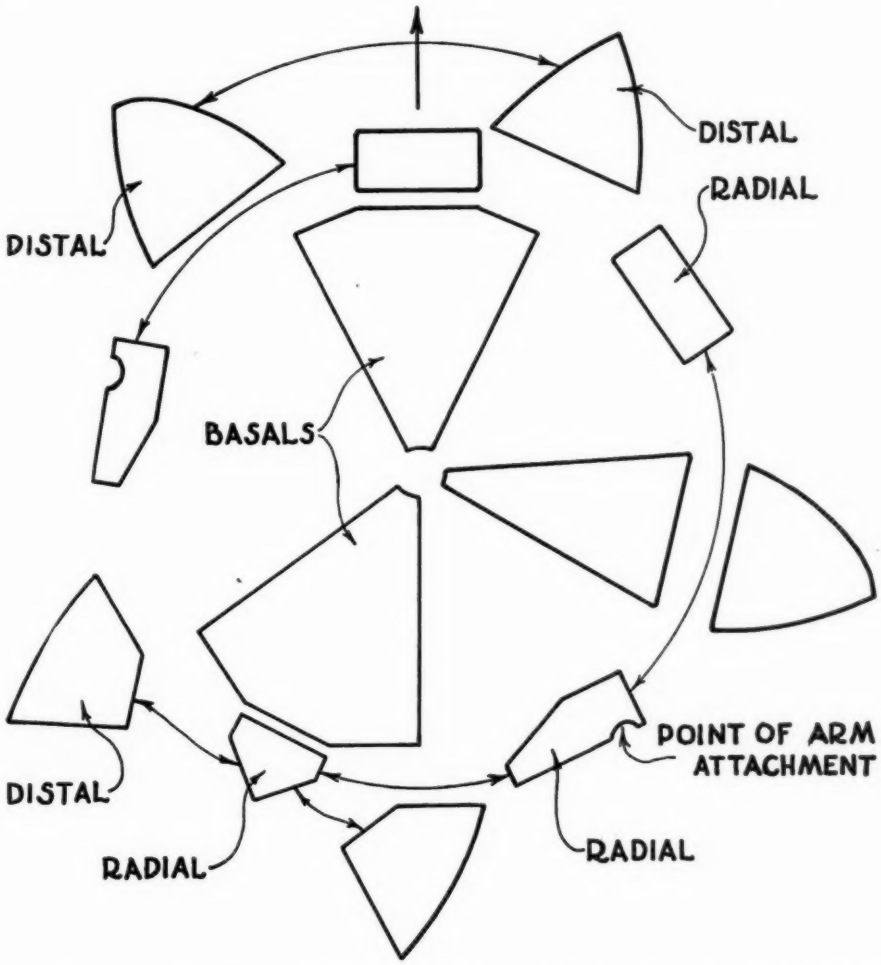

FIG. 2.—Diagrammatic plate analysis of the fourth stage of the larval development of *Mesoblastus glaber* (M. and W.).

individual. The oral hemisphere (oral view) is eccentrically placed on the basal cone, being close to the margin at the right posterior ray, and farther from the margin toward the anterior. Except for the right posterior plate, the radials are no longer continuous with the actinal hemisphere, but are commonly depressed at the lateral and margins. The radius of these pits varies up to half the height of the radial. The significance of the depressions is somewhat conjectural, but the weight of the evidence seems to indicate that they are arm facets. Several individuals bear, in one or two of their pits, calcareous particles which may be basal plates of larval arms. The distal plates

are, in this stage, larger but otherwise unchanged, except as the narrow food slits become bounded by very low ridges. This feature also may be observed on some specimens in the third stage.

METAMORPHOSIS

No further significant changes are noted until the approach of metamorphosis, which takes place as the ambital diameter increases from about 0.35 mm. to 0.4 mm. The conical base grows rapidly until it equals four-fifths of the total length. As this change is being completed, the oral surface is progressively flattened until it extends very little above the radials. Coincident with this change, the distal plates disappear. It is possible that they are simply shed, but there is some evidence, in two specimens whose distals are corroded at the tips, to suggest that they are resorbed. Even in the fourth larval stage there is a prophecy of distal plate dissolution, for many specimens are found with the distals and right posterior radial plate missing, a condition which is rare in smaller tests. The radials gradually approach horizontality and finally are depressed and modified to receive the ambulacra. Only their more recently secreted portions appear on the abactinal cone. Fully half of the radial length of the oral surface is, at first, barren of plates, thus a widely gaping mouth is formed.

POST-LARVAL DEVELOPMENT

In all the samples studied, larvae outnumber transition and post larval specimens in a ratio of approximately 50 to one, perhaps indicating, among other things, a high mortality for the younger individuals. Extended search through the larger concentrates of bulky samples is necessary to complete a series showing the essential changes leading to the adult form. Whereas, in discussing the larvae, it was convenient to group hundreds of specimens in arbitrary classes and to describe each class as a stage of development, it is now necessary to describe the characteristics of single individuals in a graded series of post larval forms.

The smallest post larval specimen found has a conical calyx 0.42 mm. long and 0.42 mm. in maximum diameter. The cone is largely made up of basal plates, and very narrow obscure radials. Growth lines are prominent, paralleling the upper margins of the basal plates. Above the serrate-carinate upper edge of the abactinal cone, plates of the flattened oral surface are only narrowly visible. As seen from above, the radials, with sutures indistinguishable, form a prominent but irregular band inside the margin. Within and rising above the radials is a small number (probably 10) of actinal plates of obscure outline. The lancets are small and show no surficial markings. The "inter-lancets" (we use this term temporarily to designate the small plates which, in the adult, bound the peristome and connect the lancets) are node-like plates, which with the lancets, bound the peristome. There is no evidence of spiracles, hydrospiric pores, or side plates. Perhaps the inner third of the radial length of the actinal surface is occupied by a large, funnel-shaped, circular mouth. Though this aperture increases slightly in size in later growth, its relative enlargement is at so slow a rate that eventually it comes to occupy a very small area in the adult.

The conical outline and relative proportions of abactinal and actinal systems is substantially the same in the next larger individual (length 0.52 mm., width 0.55 mm.). A considerable part of the expansion of the abactinal cone is due to an enlargement of the radials, which comprise about a third of the cone. The upper margin of the radial bears a broad sinus with a minor central reentrant and short lateral slopes. It is evident, however, that the broad V-shaped notch formed at the suture by adjacent lateral slopes did not, at this stage, support externally a deltoid plate. The surficial markings of the lancet plate include a terminal and two lateral lobes and a well-marked food groove. The inter-lancet plate appears as a narrow carinate crest. There is no sign of side plates or hydrospiric pores, though it is possible that both were present. The spiracle is bounded on the one side by the lancets and "inter-lancets" and on the other by the radials. The position of the anus is indicated by longer and steeper lateral slopes on the radials at the posterior inter-radius, and by a much larger spiracle. The base of the calyx is flattened just above the stem facet into a somewhat trigonal

section, and an inconspicuous node occupies the more sharply curved outline on each plate.

The next larger specimen in which the actinal system is preserved measures about 1.14 mm. in length, and 1.12 mm. in maximum diameter. Basals and radials each occupy about half of the length of the abactinal system. The cross section of the calyx at the base of the elongated radial sinuses tends to be pentagonal, due to a flattening of the radials at the lateral sutures and a slight inward deflection of their limbs above. From this stage on, the conical outline is progressively modified, and is soon entirely lost. The slight re-entrant or crest in the bottom of the sinus in the last specimen described is more prominent in this and still larger specimens. The upper limbs of the radials terminate in points which do not include the deltoid plates, though these are now present as oral crests invading the spiracles. The anal inter-radius is destroyed. The lancet plate includes five or six lobes on each side, with side plates and hydrospiric pores. This is the smallest specimen whose side plates share with the lancets and "interlancets" in bounding the spiracles. The mouth is, and throughout further development of the species remains, pentagonal, with rays at the food grooves. The ambulacra exceed slightly one-third of the total length of the calyx as viewed from the side.

A slightly larger specimen, which unfortunately has disintegrated, provides information on the anal inter-radius. The tips of adjacent radial limbs are beveled to form a broad V-shaped notch, just inside which lies a large anal opening confluent with the spiracle. There is here no evidence of a deltoid ridge (oral crest).

A still larger and slightly distorted specimen, length 1.45 mm., width 1.45 mm., bears four small nodose, elongate deltoids terminating the radial limbs. The fifth or anal deltoid is missing, but, from larger specimens, it may be inferred that it was truncated above, and lay further from the peristome than the other deltoids.

From the stage in development just described to that of the largest individuals, no essential changes occur except those involving shape of calyx, relative proportions of the abactinal plates, and outline and number of plates of the ambulacra. The basal plates increase in size very slowly, and most of their growth is at the sides. They thus tend to flatten out, lying eventually in the center of the slightly convex pentagon determined by the ends of the radial sinuses. The inconspicuous nodes, first seen at the base of the second post-larval individual, have expanded laterally to form a discontinuous, and horizontally directed, carinate frill at the stem facet, just above which the base is somewhat nodose for approximately a millimeter. The radials have expanded and elongated rapidly, and the radial sinus extends to a level slightly above the base. Four of the deltoids are broadly triangular, strongly nodose, recumbent, and produced into sharp oral crests. The short anal deltoid folds laterally about the large elongate anus, which is confluent with the left lobe of its spiracle. The ambulacra are very narrow. The calyx becomes barrel-shaped, flattened below and above, the inter-radii broadly impressed, the ambulacra elevated in cross section. The maximum length is approximately 6 mm., maximum diameter 5 mm.

ONTOGENY OF PENTREMITES PRINCETONENSIS Ulrich

FIRST STAGE

The smallest larvae of *Pentremites princetonensis* which can be recognized as such are slightly ovate calcareous bodies with average measurements of 0.17 mm. in length and 0.125 mm. in width at the ambitus, the greatest diameter being at the top of the radials. These larvae are with difficulty distinguished from those of the first stage of *Mesoblastus glaber* since there is enough individual variation in both species to cause an apparent intergradation of form in their earliest stage of development. The larvae of *Pentremites princetonensis* generally, however, are more elongate, being somewhat drawn out proximally, and they are usually distinctly truncated at the large stem facet. The upper stem plate is larger than the second (only two have been found on any one specimen), and is in some cases distinguished from the calyx only by close examination. No single specimen found is well enough preserved to afford a complete plate analysis, but the evidence gleaned

from a number of individuals suggests strongly that the plate arrangement of the first stage of this species is the same as that described for the second stage of *Mesoblastus glaber*.

SECOND STAGE

In its second stage, the larva of *Pentremites princetonensis* exhibits considerable variation in proportions. Among the smaller specimens, proportions vary from 0.238 mm. length and 0.154 mm. width to 0.224 mm. length and 0.168 mm. width. Among larger specimens proportions vary correspondingly from 0.294 mm. length and 0.182 mm. width, to 0.3 mm. length and 0.238 mm. width. Most of this variation occurs in the length and hence in the angle of the basal cone, containing radial and basal plates, the latter of which are most affected by changes in proportion.

There are three basals. The smaller one occupies the left anterior interray (basal view), and is flattened to gently convex above, without appreciable apical angulation. The upper margin of the left posterior basal is horizontal in the middle, with straight flanking slopes. The third basal is flattened above.

The anterior and right anterior radials are rectangular; the left posterior radial is triangular and occupies a position in the lower zone of the distal series, its lower margin being near the general level of the tops of

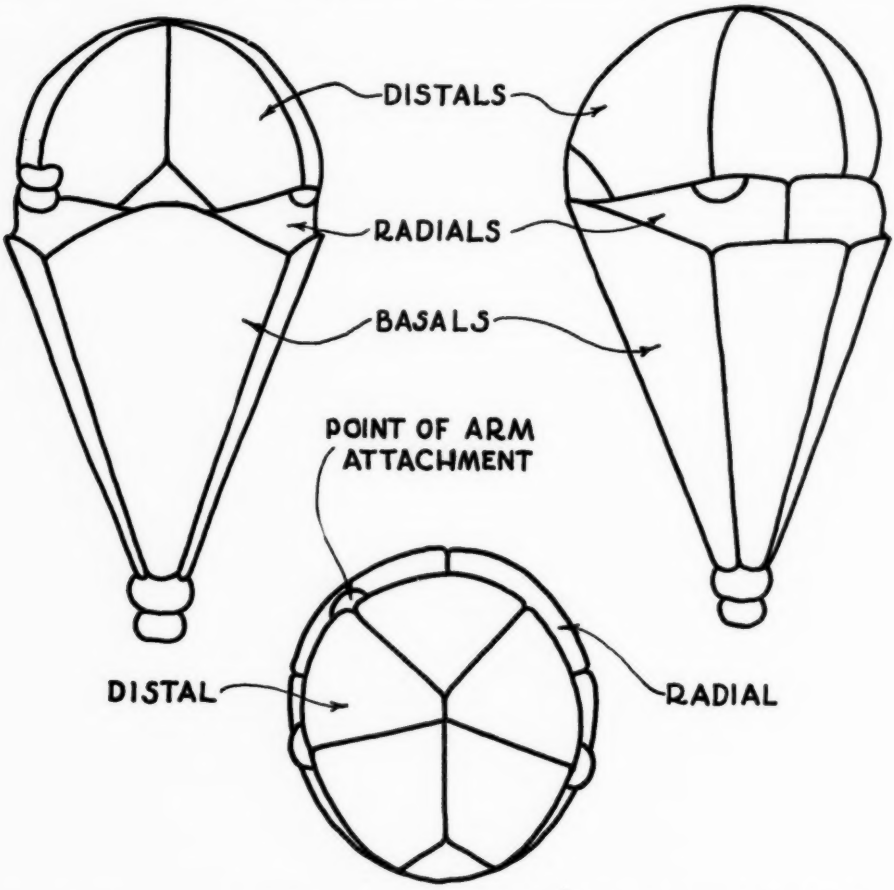

FIG. 3.—Diagrammatic ventral and lateral views of the fourth stage in the larval development of *Pentremites princetonensis* Ulrich.

the other radials. The adjoining radials are acuminate at one end, the points helping to support the smaller triangular radial. In this latter feature, the larvae of *Pentremites princetonensis* differ from those of *Mesoblastus glaber*, in which species the flanking inflections of the grooves, or by the slightly greater growth of one radial at the expense of those adjoining. In this second stage there is already observable a slight eccentricity of curvature of the oral hemisphere as seen from the right or left side, the slope

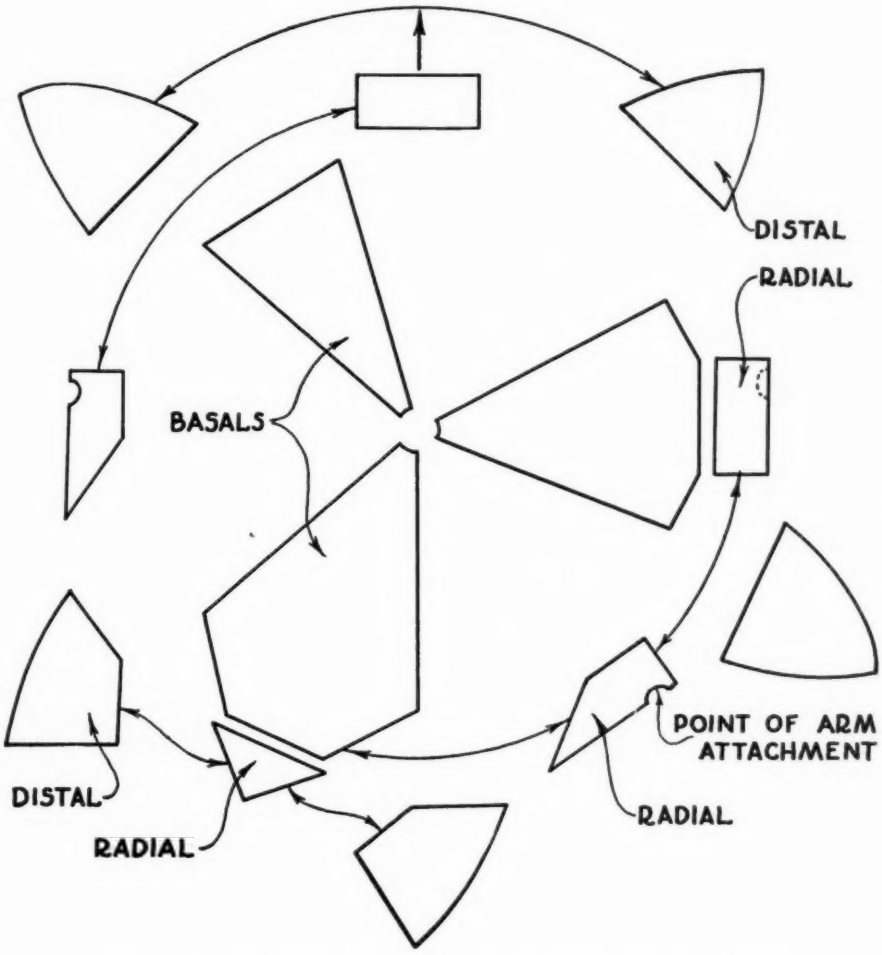

FIG. 4.—Diagrammatic plate analysis of the fourth stage in the larval development of *Pentremites princetonensis* Ulrich.

radials meet the small radial along short vertical sutures. Three of the distals in *Pentremites princetonensis* are triangular, and the other two have their adjoining lower angles truncated by the small triangular radial. In general, the food grooves meet orally as indicated in figure 3, but there are numerous minor variations, caused by slight being gentlest at the left posterior radial (basal or plan view), steepest opposite. Thus in general aspect, as in plate arrangement, the second stage of *Pentremites* closely resembles the third stage of *Mesoblastus*, with these exceptions: the former is more extended basally, the basals are proportionately longer, and the keel described for the

latter genus is, in *Pentremites*, observable only as a slight angulation at the tops of the radials.

THIRD STAGE

In the third stage, position of maximum diameter has shifted to the tops of the basals, and variations in proportion are more striking than before. Measurements for average sized individuals vary from 0.406 mm. length and 0.224 mm. diameter, to 0.406 mm. length and 0.28 mm. diameter. No notable changes other than in size occur, except for the appearance on some of the radials of arm facets, to which, in some specimens, one or two arm plates are still attached. At least half of the individuals, however, bear no arms. Of the remainder, at least 70 per cent have only one arm facet, in the right posterior ray (aboral or plan view), about 20 per cent have an additional arm at the left anterior ray, and about 10 per cent have a third arm at the right anterior ray. Those food slits terminating at arms commonly extend distally in broad, shallow furrows, which do not, however, reach the food groove junctions.

FOURTH STAGE

In the fourth stage, measurements vary from 0.56 mm. length and 0.285 mm. width for lean specimens, and 0.532 mm. length and 0.364 mm. width for obese individuals. Two-armed individuals (arm placement as described for the third stage) occur, but three-armed individuals predominate. An occasional individual approaching the stage of distal reorganization may have four-arm facets, only the small radial being without one. Throughout growth of the larva, the basal plates tend to comprise more and more of the entire calyx, until at the beginning of metamorphosis they may comprise two-thirds of the length of the calyx.

METAMORPHOSIS

The metamorphosis of the *Pentremites* larva in the main parallels that described for *Mesoblastus*, therefore the process will not be discussed in detail in this preliminary paper.

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STUDIES OF CARBONIFEROUS AMMONOIDS: PARTS 1–4

A. K. MILLER and W. M. FURNISH

ABSTRACT—In part one representatives of the following ammonoid genera are illustrated and described from the Mississippian Meramec series of Rockcastle County, Kentucky: *Neoglyphioceras*, *Goniatites* s. s., *Girtyoceras*, and *Dimorphoceras*. A variety of nautiloids which occurs in association is included, and one new genus, *Tripteroceroides*, is established. The fauna is correlated with that of the lower Caney and equivalent beds in North America and the uppermost Viséan of Europe.

In the second part *Girtyoceras meslerianum* amd *Lyrogoniatites newsomi georgiensis*, n. var., are described from the Floyd shale north of Rome, Georgia. The latter is the genotype of the new genus *Lyrogoniatites*. Both species occur also in the lower Caney shale of Oklahoma and in the upper *Posidonomya* (Bisat's P_2) zone in the upper Viséan of Europe.

In part three *Epicanites loeblichi*, n. sp., is described from the lower portion of the Caney shale of Oklahoma. It occurs in association with *Goniatites* s. s. and *Girtyoceras* and is therefore Meramec in age. A new subgenus of *Daraelites*, *Boesites*, is proposed with *D. texanus* Böse as type.

The fourth part deals with three new species, *Cravenoceras hesperium*, *C.? nevadense*, and *Anthracoceras? colubrellus* from east-central Nevada. It is concluded that the faunas probably are Chester in age.

I. MISSISSIPPIAN (MERAMEC) AMMONOIDS FROM EASTERN KENTUCKY

DURING THE last few years a number of small collections of Carboniferous ammonoids have become available to us for study. Most of these are not particularly important in themselves, but collectively they add considerably to our knowledge of the faunas and strata involved. We propose to publish a series of short papers on these collections, of which the present study is the first.

The occurrence of Mississippian ammonoids in eastern Kentucky was first recorded by S. A. Miller in 1889, who briefly described *Goniatites kentuckiensis* and *G. subcircularis* from near Crab Orchard in Rockcastle County. In 1892, Miller and Faber described from the same locality two additional species, *G. limatus* and *G. leviculus*, and four years later Miller and Gurley described some topotypes of *G. kentuckiensis*. In 1903 J. P. Smith restudied certain of these specimens but otherwise little has been added to our knowledge of this fauna. *G. subcircularis* has been identified from Arkansas, and European paleontologists have referred to it specimens from various localities in Europe and northern Africa. The other three species have been so poorly known that they have been neglected by most paleontologists.

Dr. J. Brookes Knight of Princeton University loaned us for study a large collection of cephalopods assembled long ago (1892?) by Moritz Fisher at presumably the same locality from which the type specimens came. At our request Professor C. O. Dunbar sent us from the Yale Peabody Museum additional material collected by Moritz Fisher, Dr. K. E. Caster of the University of Cincinnati loaned us a few specimens from near-by localities, and Professor Carey Croneis of the University of Chicago made it possible for us to study the type specimens of *Goniatites limatus* and *G. leviculus*. Mr. F. O. Thompson of Des Moines, Iowa, has generously supplied financial aid for the preparation of these studies. The photographs were retouched and the diagrammatic figures were completed by Mr. Howard Webster.

With the exception of one individual, all of the several hundred specimens that we are studying are of the same unique lithology, and presumably all came from the same horizon and general locality. All of the previously described specimens are stated to have come from the "St. Louis" at Crab Orchard, Rockcastle County, Kentucky. The bulk of the material now available came from some unrecorded locality in Rockcastle County. Neither Charles Butts nor the late August F. Foerste, who were much more than ordinarily familiar with

the Mississippian of Kentucky, could tell us the precise locality at which these cephalopods occur. In this vicinity there is a considerable thickness of Mississippian strata which might have yielded this fauna. All of the specimens available are completely silicified, uncrushed, and entirely free of matrix.

land and in beds which presumably are equivalent in age in western Europe, in European and Asiatic Russia, and in northern Africa.

Altogether the following species of cephalopods are known from the Meramec series of Rockcastle County, Kentucky:

British Zones of Bisat		German Zones of Schmidt	Western Europe		North America		Arkansas-Oklahoma	Texas	Nevada	Kentucky	Georgia
Homoceras Zone	H	III δ	Upper Namurian	Upper Carboniferous	Pennsylvanian	Morrow	Morrow	Bend			
Eumorphoceras Zone	E_2	III δ	Lower Namurian	Upper Carboniferous	Mississippian	Chester	Pitkin			Chester	
	E_1	III δ	Lower Namurian	Upper Carboniferous	Mississippian	Chester	Fayetteville, Upper Caney	Upper Barnett, Upper Helms	White Pine		
Goniatites or Posidonomya Zone	P_2	III γ	Upper Viséan	Lower Carboniferous	Mississippian	Chester	Batesville, Lower Caney	Lower Barnett, Lower Helms		Meramec	Floyd
	P_1	III β	Upper Viséan	Lower Carboniferous	Mississippian	Chester	Moorefield				
Beyrichoceras Zone	B	III α	Middle Viséan	Lower Carboniferous	Mississippian	Meramec					

TABLE 1.—COMPARISON OF EUROPEAN MIDDLE CARBONIFEROUS FAUNAL ZONES AND CERTAIN AMERICAN AMMONOID-BEARING BEDS.

Their appearance suggests that they came from residual material resulting from the weathering of limestone.

The ammonoids, taken by themselves, indicate clearly that the fauna is of Mississippian (Meramec) age and corresponds to faunas known from the *Goniatites* zone of the Caney shale of Oklahoma, the Moorefield shale and the Batesville sandstone of Arkansas, the Barnett shale of central Texas, the Helms formation of west Texas, and the Floyd shale of Georgia. In the Eastern Hemisphere this fauna is represented in the lower Bowland shale of northern Eng-

Neoglyphioceras subcirculare (Miller)
Goniatites kentuckiensis Miller
Girtyoceras limatum (Miller and Faber)
Dimorphoceras edwini Miller and Furnish, n. sp.
Bactrites quadrilineatus Girty
Mooreoceras sp.
Mooreoceras cf. *M. choctawense* (Girty)
Cycloceras ballianum Girty
Tripteroceroides knighti Miller and Furnish, n. sp.
Discitoceras sulcatum (Sowerby)
Solenochilus sp.

In western Europe, where Middle Car-

boniferous ammonoid zones have been well established and their relationships carefully worked out, the genus *Goniatites* s. s. is represented in only the Viséan; that is, in northern England it occurs in Bisat's *Beyrichoceras* (B) and *Posidonomya*[1] (P_1 and P_2) zones, and in Germany it ranges through Schmidt's IIIα–γ. *Neoglyphioceras* is characteristic of the uppermost Viséan (P and IIIγ). It is widespread and abundant in this zone and is probably confined to it. *Girtyoceras*, like *Goniatites*, ranges through the middle and the upper Viséan (B-P_2, and IIIα–γ). Representatives of the genus *Dimorphoceras* that are similar to *D. edwini* are common in the upper Viséan and the Namurian. *Bactrites* and the various nautiloid genera represented in the Kentucky fauna are known to have a long range in the Carboniferous, but *Discitoceras sulcatum*, a unique form seems to be widespread in the upper Viséan.

Almost all of the cephalopod species we are studying occur also in the well-known fauna of the Caney shale of Oklahoma. It seems that two distinct ammonoid zones are represented in the Caney shale. The lower of these, of Meramec age, which is the one represented in Kentucky and in the uppermost Viséan (P_2 and IIIγ), is characterized by the genera *Goniatites* and *Neoglyphioceras*; whereas the upper, of Chester age, which is characterized by *Eumorphoceras*, corresponds to the lower Namurian of western Europe, that is, to the *Eumorphoceras* (E) zone of Bisat and Zone IIIδ of Schmidt.

Bactrites is represented in the Kentucky Mississippian fauna by one species (pl. 45, fig. 5), which is indistinguishable from *B. quadrilineatus* of the Caney. Similar forms are widespread in the Carboniferous and the Permian.

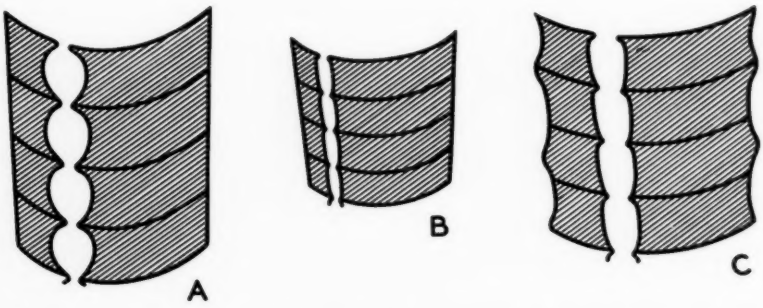


FIG. 1.—Longitudinal dorso-ventral sections, ×2½, of (A) *Mooreoceras* sp.; (B) *Tripteroceroides knighti* Miller and Furnish, n. sp.; and (C) *Cycloceras ballianum* Girty.

In the collections we are studying, the most abundant nautiloid is a species of *Mooreoceras* which is quite typical of the genus (pl. 45, figs. 10, 11). Most of the available specimens are silicified and rather poorly preserved. In diameter they range up to some 15 mm. The siphuncle is subcentral and is composed of segments that are expanded within the camerae (text fig. 1A). A few congeneric specimens have prominent transverse ornamentation (pl. 45, fig. 14), and presumably these represent a distinct species which resembles *M. choctawense* of the Caney.

The genus *Cycloceras* is abundantly represented in the Mississippian of Kentucky by specimens (pl. 45, figs. 6, 7) which appear to be referable to *C. ballianum*, originally described from the Caney. The nature of the siphuncle of the genotype of *Cycloceras* is not well known, but in the forms under consideration the siphuncle is subcentral in position and is cyrtochoanitic in structure (text fig. IC).

Another abundant species in the available collections does not seem to be referable to any described genus, and we here propose the name *Tripteroceroides* for it and designate *T. knighti* as genotype. The conch is

[1] In part synonymous with *Caneyella* (Bisat, 1924, pp. 87–88).

straight throughout most of its length, but its adapical portion is distinctly curved dorsally. At least the phragmacone is depressed dorso-ventrally and is subelliptical in cross section, being more strongly flattened ventrally than dorsally. Adolescent stages of the conch are, however, more nearly circular than mature ones. All of the type specimens are septate throughout. They are expanded orad rather gradually and attain a maximum width of at least 14 mm. The internal mold is smooth, but some specimens show faint longitudinal lirae, that is, raised lines, which are parallel to the lateral zones of the conch but converge along the dorsum (pl. 45, fig. 13). Only a very few of the type specimens portray these lirae, and therefore they may be due to individual variation or to preservation. On the mature portion of the conch each suture forms slight ventral and dorsal lobes and similar lateral saddles. The ventral lobe is more pronounced than the dorsal. The siphuncle is subventral but not marginal in position, is relatively small, and is cyrtochoanitic in structure (text fig. 1B). *Orthoceras hibernicum* Foord of the Mountain limestone of Ireland and *O. cucullus* de Koninck of the Viséan of Belgium may be congeneric with the species under consideration, but they are much larger. *Tripteroceroides* is probably not at all closely related to *Tripteroceras* of the Early Paleozoic, which it superficially resembles.

FIG. 2.—Cross section of *Tripteroceroides knighti* Miller and Furnish, n. sp., ×2½.

Coiled nautiloids appear to be rare in the Mississippian of eastern Kentucky, but we have two specimens that appear to represent *Discitoceras sulcatum* (pl. 45, figs. 8, 9) and two that are referable to the genus *Solenochilus* (pl. 45, figs. 3, 4). *D. sulcatum* is an easily recognized species which has been recorded from a number of localities in Europe and may be characteristic of the late Mississippian. The genus *Solenochilus* has a long range in the Carboniferous and the Permian, and since the specific affinities of the small specimens in the collections we are studying can not be determined, they have no particular stratigraphic significance.

FIG. 3.—Cross section of *Discitoceras sulcatum* (Sowerby), ×2½.

SYSTEMATIC PALEONTOLOGY

Genus NEOGLYPHIOCERAS Brüning, 1923

This genus includes longitudinally lirate goniatitids which occur in the uppermost Viséan. The genotype, *Goniatites spiralis* Phillips, is laterally compressed and has a moderate-sized umbilicus. Some representatives of the genus, such as *N. newsomi* (Smith) are more nearly globular and have a relatively large umbilicus. We are designating *Goniatites subcircularis* Miller as the genotype of *Lusitanoceras* Pereira de Sousa, and that generic name then becomes a synonym of *Neoglyphioceras*, which has priority. The genotype of *Paragoniatites* Librovitch (1938, pp. 54, 90) is *Gastrioceras caneyanum* Girty, a typical representative of *Neoglyphioceras*, and therefore *Paragoniatites* should be suppressed as a synonym.

Neoglyphioceras bellilineatum Miller and Owen and "*Gastrioceras*" *retiferum* Miller and Owen, which occur higher in the Carboniferous, have sutures that are considerably more advanced, and these forms may not be at all closely related to the type of *Neoglyphioceras*. We are therefore proposing a new name, *Owenoceras*, for these two species and designating *Neoglyphioceras bellilineatum* Miller and Owen of the Pennsylvanian Cherokee shale of Missouri as genotype. The genus *Owenoceras* is characterized by a subglobular conch, a moderately large umbilicus, numerous longitudinal lirae particularly prominent on the exterior of the test, and a gastrioceran suture; in some cases umbilical nodes are present. *Cravenoceras* and similar forms may be differen-

tiated by means of the ornamentation alone. *Neoglyphioceras* has a simpler suture, fewer lirae, and is apparently restricted to a considerably older horizon.

NEOGLYPHIOCERAS SUBCIRCULARE (Miller)

Plate 45, figures 1, 2;
Plate 47, figures 13, 14

Goniatites subcircularis MILLER, *1889*, North American geology and palaeontology for the use of amateurs, students, and scientists, p. 440, text fig. 741; SMITH, *1903*, U. S. Geol. Survey Mon. 42, pp. 81–82, pl. 26, figs. 14–18; GIRTY, *1911*, U. S. Geol. Survey Bull. 439, p. 101, pl. 14, figs. 7, 8; BISAT, *1924*, Yorkshire Geol. Soc., Proc., n. ser., vol. 20, p. 78; DELÉPINE, *1930*, Livre Jubilaire (1830–1930) Soc. géol. France, tome 1, pp. 220, 224, 225, 228; —, *1931*, C. R. Cong. Soc. Savantes, Lille, 1928, pp. 134–135; —, *1931*, British Assoc. Adv. Sci., Rept. 1930, p. 327; BISAT, *1933*, Geol. Assoc., Proc., vol. 44, p. 258; BÖHM, *1935*, Études sur les faunes du Dévonien Supérieur et du Carbonifère Inférieur de la Montagne Noire, pp. 148–149, pl. 8, figs. 1a–c; DELÉPINE, *1935*, Soc. géol. France, Bull., 5e sér., tome 5, pp. 179–180, 185, 186, 187, pl. 7, figs. 14–17; MOORE, *1936*, Manchester Geol. Assoc., Jour., vol. 1, p. 184, pl. 1, figs. 3–5, 9; BISAT, *1936*, Internat. Geol. Cong., Rept. 16th sess., vol. 1, p. 535; DELÉPINE, *1937*, C. R. Deuxieme Cong. l'avanc. études Stratigr. Carbon; Heerlen, 1935, pp. 144, 146; DELÉPINE and MENCHIKOFF, *1937*, Soc. géol. France, Bull., 5e sér., tome 7, p. 86.

?Gastrioceras caneyanum GIRTY, *1909*, U. S. Geol. Survey Bull. 377, pp. 57–59, pl. 12, figs. 4–10; —, *1911*, U. S. Geol. Survey Bull. 439, pp. 102–103, pl. 14, figs. 6; —, *1915*, U. S. Geol. Survey Bull. 593, p. 131, pl. 5, figs. 6, 6a.

?Goniatites subcircularis zousfanensis DOLLÉ, *1912*, Soc. géol. Nord, Ann., tome 41, pp. 216–217, pl. 7, figs. 7, 7a.

Lusitanoceras subcirculare Pereira de Sousa, *1924*, Soc. géol. France Bull., 4e sér., tome 23, p. 304.

Glyphioceras subcirculare [part] SCHMIDT, *1925*, Preuss. geol. Landesanstalt, Jahrb., Bd. 45, pp. 572–574, pl. 21, figs. 12, 13, pl. 24, figs. 1–3; —, *1929*, Tiersiche Leitfossilien des Karbon, Gürich's Leitfossilien, Lief. 6, p. 68, pl. 18, fig. 8.

Neoglyphioceras subcirculare PLUMMER and SCOTT, *1937*, Texas Univ. Bull. 3701, pp. 116, 186, 187, 381, 383, 399, 401.

?Neoglyphioceras caneyanum PLUMMER and SCOTT, *1937*, Texas Univ. Bull. 3701, p. 15, 186, 187, 381, 383.

?Paragoniatites caneyanus LIBROVITCH, *1938*, Arctic Inst., Trans., vol. 101, pp. 54, 90.

The following description is based entirely on topotypes from eastern Kentucky, where the species is abundant. Conch subdiscoidal and phragmacone attains a diameter of at least 17 mm. Umbilicus small and steep-sided (text fig. 4A). Our specimens, all

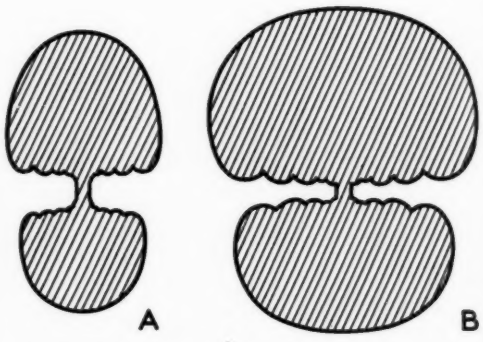


FIG. 4.—Cross sections, ×4, of (A) *Neoglyphioceras subcirculare* (Miller) and (B) *Goniatites kentuckiensis* Miller.

of which are internal molds, bear some 32 longitudinal lirae. These are subangular with rounded grooves between them and are more closely spaced on the ventral than on the lateral zones of the conch. The specimens bear sinuous transverse constrictions, of which typically there are four to the volution. These constrictions are more prominent on the lateral than on the ventral zones of the conch. They form flattened ventral salients and rounded lateral sinuses.

Each mature suture forms a relatively small narrow divided ventral lobe and on either side of it a rounded first lateral saddle, a broad V-shaped first lateral lobe, and a low broad rounded second lateral saddle which extends to a lobe on the umbilical wall (text figure 5). The dorsal lobe is relatively deep, narrow, and pointed; the adjacent internal lateral lobes are similar but smaller and the saddles are rounded.

Remarks.—This species is closely related to *N. spirale* (Phillips), and Bisat has stated that the two may be conspecific. *Gastrioceras caneyanum* Girty may also be a synonym of *N. subcirculare*, and *Goniatites entogonus* Gabb and *G. newsomi* Smith are closely related but have broader conchs and larger umbilici.

Occurrence.—The original type specimens

of this species came from the Mississippian, "St. Louis," near Crab Orchard, Rockcastle County, Kentucky, and we have many additional specimens from the same general vicinity. Forms that are very closely similar

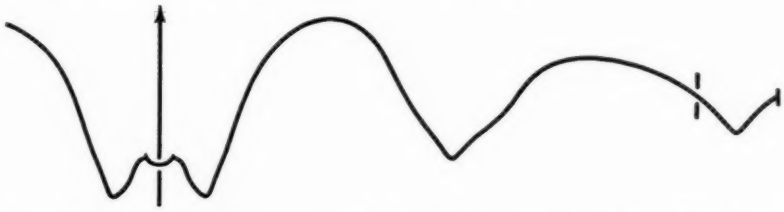


FIG. 5.—A mature external suture of *Neoglyphioceras subcirculare* (Miller) at a diameter of about 12 mm., ×10.

and may be conspecific have been recorded from the Caney of Oklahoma, the Moorefield and Batesville of Arkansas, the Barnett of Texas, the upper *Posidonomya* zone (P_2) of northern England, the Mountain limestone of Ireland, the upper Viséan of Belgium and France, zone IIIγ of Germany, and the Viséan of Morocco and northern Algeria.

Figured specimens.—Paleontological collections of Princeton University.

GONIATITES KENTUCKIENSIS Miller
Plate 46, figures 1–13

Goniatites kentuckiensis MILLER, *1889*, North American geology and palaeontology for the use of amateurs, students, and scientists, pp. 439–440, text fig. 740; MILLER and GURLEY, *1896*, Illinois State Mus. Nat. Hist. Bull. 11, pp. 40–41, pl. 5, fig. 1; SMITH, *1903*, U. S. Geol. Survey Mon. 42, p. 77, pl. 17, fig. 1; PLUMMER and SCOTT, *1937*, Texas Univ. Bull. 3701, p. 114.

?Glyphioceras cumminsi HYATT, *1893*, Texas Geol. Survey, Ann. Rept. 4, pp. 467–471, pl. 47, figs. 33–43.

?Goniatites striatus SMITH, *1903*, U. S. Geol. Survey Mon. 42, pp. 80–81, pl. 10, figs. 1–11, pl. 26, figs. 6–13.

?Goniatites choctawensis [part] GIRTY, *1909*, U. S. Geol. Survey Bull. 377, pp. 59–62, pl. 13, figs. 1–11b.

?Goniatites choctawensis [part] PLUMMER and SCOTT, Texas Univ. Bull. 3701, pp. 113–114, pl. 7, figs. 3–6.

Goniatites s. s. is one of the most widespread and abundant of the Carboniferous ammonoid genera, but it is restricted stratigraphically and is characteristic of the upper Viséan horizon. All species are closely related and are more or less gradational with other representatives of the genus, for individual species in some cases show considerable variation (text fig. 6). Specific subdivisions are for the most part based on differences in surface ornamentation. S. A. Miller's original types of *G. kentuckiensis* were internal molds; but subsequently together with Gurley, he described and illustrated a testiferous specimen, and we have similar topotypes (pl. 46, fig. 3). Unfor-

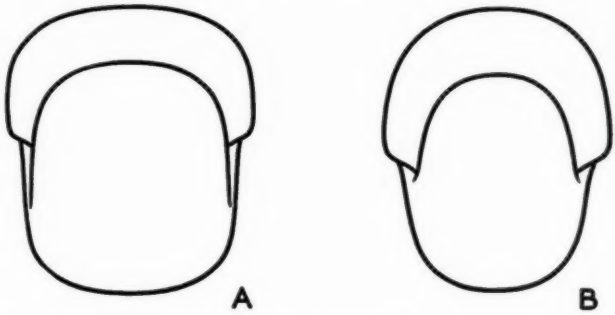


FIG. 6.—Outline ventral views of *Goniatites kentuckiensis* Miller, ×2½.

tunately, all of our specimens are silicified, and therefore their surface ornamentation is not as well preserved as is that of many calcareous specimens. Nevertheless, the available material makes it clear that the surface of the mature test of *G. kentuckiensis* is of the *Goniatites striatus* type (pl. 46, fig. 11). In northern England, *G. striatus* occurs with similar forms that bear transverse as well as longitudinal markings. These forms are generally regarded as specifically distinct and are grouped with *Goniatites crenistria*. The name *G. kentuckiensis* was proposed for American representatives of the genus *Goniatites* that have surface markings like *G. striatus*, and as nearly as can be determined from Shumard's description, the name *G. choctawensis* was originally applied to American forms with ornamentation like *G. crenistria*—the types of *G. choctawensis* have been lost. *G. cumminsi* was proposed by Hyatt for forms like *G. striatus*, and its type specimens seem to be indistinguishable from *G. kentuckiensis*. The specimen represented by figure 10 of Plummer and Scott's plate 7 of 1937 appears to be the syntype of

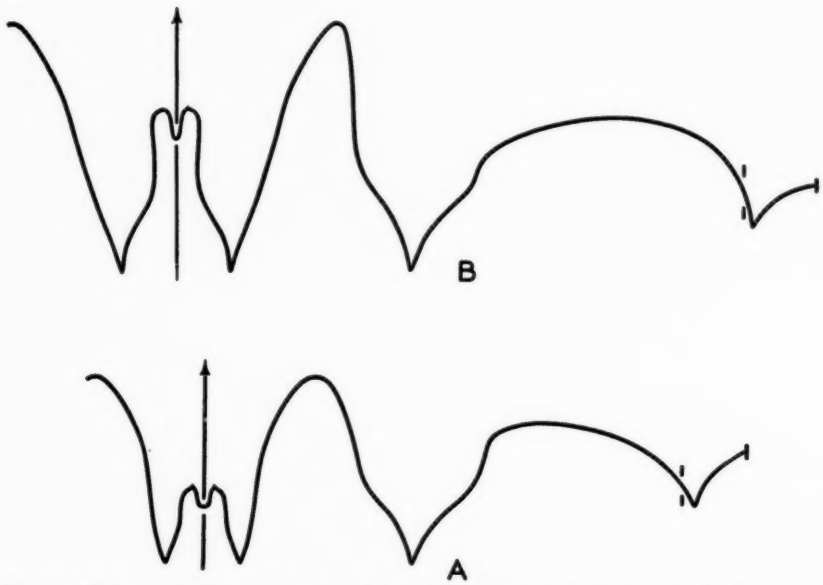
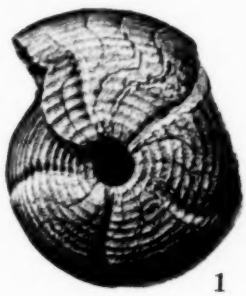


FIG. 7.—Sutures of *Goniatites kentuckiensis* Miller at diameters of about 15 mm. and 55 mm. A is ×6, B is ×2½. B is based on the specimen represented by figures 12 and 13 on plate 46.

EXPLANATION OF PLATE 45

All specimens illustrated are from the Mississippian Meramec series of Rockcastle County, Kentucky, and all belong to Princeton University.

FIGS. *1, 2—Neoglyphioceras subcirculare* (Miller). A hypotype of moderately large size. ×2. (p. 360)
3, 4—Solenochilus sp. A small poorly preserved internal mold, × 2. (p. 359)
5—Bactrites quadrilineatus Girty. Ventral view of a hypotype, ×2. (p. 358)
6, 7—Cycloceras ballianum Girty. A small hypotype, ×2; and a larger one, ×1½. (p. 358)
8, 9—Discitoceras sulcatum (Sowerby). A well-preserved fragment, ×1½. (p. 359)
10, 11—Mooreoceras sp. Two specimens, ×1½. (p. 358)
12, 13—Tripteroceroides knighti Miller and Furnish, n. sp. Dorsal views of two of the syntypes, ×2. (p. 358)
14—Mooreoceras cf. *M. choctawense* (Girty). Part of a phragmacone with a portion of the test preserved, ×2. (p. 358)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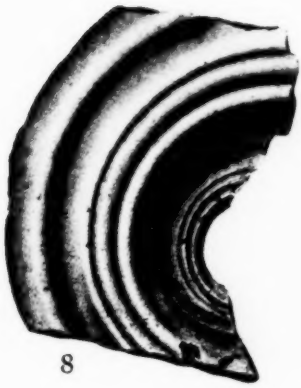
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Miller and Furnish, Carboniferous Ammonoids

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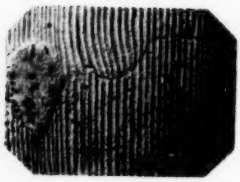
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Miller and Furnish, Carboniferous Ammonoids

Goniatites cumminsi that is represented by figures 36 and 37 on Hyatt's plate 47 of 1893.

Sutures of *G. kentuckiensis* vary considerably during ontogenetic development (text fig. 7) and equal-sized specimens show appreciable though gradational differences in the shape of the conch (text figs. 6A and 6B; pl. 46, figs. 7, 8 and 9, 10). Also, some specimens show prominent transverse constrictions whereas others do not (pl. 46, figs. 1, 2 and 9, 10). As a general rule, the globular specimens with flattened venters (text fig. 6A) also possess transverse constrictions and seem to be otherwise more primitive than the normal or compressed forms (text fig. 6B). In view of the fact that fully mature specimens, such as that represented by figures 12 and 13 on plate 46, seem to show little variation, and since the shape of the conch is S. A. Miller's figured type is not known, it is impossible to establish logical subdivisions of this species.

Occurrence.—S. A. Miller's original type specimens and those studied by Miller and Gurley came from the "St. Louis" near Crab Orchard, Rockcastle County, Kentucky. In addition to numerous topotypes which are now available to us, we have three specimens from the S. A. Miller collection, now at the University of Cincinnati, Two of these, which are of the same lithology as the topotypes, came from near Lebanon, Marion County, about 50 miles west of the type locality; and the third, which is preserved in limestone, came from some unrecorded locality.

Types.—The original figured type has apparently been lost; however, the specimen figured by Miller and Gurley and by Smith is at the Walker Museum, University of Chicago. Numerous topotypes, including the specimens we are figuring, are in the paleontological collections of Princeton University. Three other specimens are at the University of Cincinnati.

Genus GIRTYOCERAS Wedekind, 1918

Adelphoceras GIRTY, *1909*, U. S. Geol. Survey Bull. 377, pp. 64–66; WEDEKIND, *1914*, Mitt. Mus. Stadt Essen, Heft 1, p. 11.—PLUMMER and SCOTT, *1937*, Texas Univ. Bull. 3701, pp. 173–174. [Not *Adelphoceras* Barrande, 1874.]

Girtyoceras WEDEKIND, *1918* [Jan.], Palaeontographica, Bd. 62, p. 140; BRÜNING, *1923*, Geol. Archiv., Bd. 1, Heft 5, p. 265; MILLER, *1934*, Am. Jour. Sci., 5th ser., vol. 28, p. 33.

Sagittoceras HIND, *1918* [Oct.], Geol. Mag., vol. 65, pp. 446–447; BISAT, *1924*, Yorkshire Meol. Soc. Proc., n. ser., vol. 20, pp. 72, 82–83; —BISAT, *1928*, C. R. Cong. l'avanc. études Stratigr. Carbon.—Heerlen, 1927, p. 125.—SCHMIDT, *1929*, Tiersiche Leitfossilien des Karbon, Gürich's Leitfossilien, Lief. 6, p. 69.—KOBOLD, *1932*, Preuss. geol. Landesanst., Jahrb., Bd. 53, pp. 503–506.—BISAT, *1933*, Geol. Assoc., Proc., vol. 44, p. 256.—MILLER, *1934*, Am. Jour. Sci., 5th ser., vol. 28, pp. 31–36.—BISAT, *1934*, Yorkshire Geol. Soc., Proc., n. ser., vol. 22, p. 297; MOORE, *1936*, Manchester Geol. Assoc., Jr., vol 1, p. 137; DELÉPINE and MENCHIKOFF, *1937*, Soc. géol. France Bull., 5e sér., tome 7, pp. 82–83; PLUMMER and SCOTT, *1937*, Texas Univ. Bull. 3701, pp. 324–325.

Dryochoceras MORGAN, *1924* [Oklahoma], Bur. Geol. Bull. 2, p. 185.

Beyrichoceras [part] BISAT, *1924*, Yorkshire Geol. Soc., Proc., n. ser., vol. 20, pp. 72, 83–84.

Homoceras [part] SCHMIDT, *1925*, Preuss. geol. Landesanstalt, Jahrb., By. 45, pp. 575–577.

In 1918 Wedekind noted that Girty's generic name *Adelphoceras* was preoccupied, and he proposed the name *Girtyoceras* for the genus, listing *Adelphoceras meslerianum* Girty as genotype. Since that time, two other generic names, *Sagittoceras*[2] and *Dryochoceras*, have been proposed for related forms. Both of thesegenera were stated to be characterized by the acute periphery and lenticular shape of their conchs. When they were named it was not known that the genotype of *Girtyoceras* also develops an acute venter at full maturity (pl. 47. figs. 4, 5). Furthermore, it now seems probable that the genoholotype of *Dryochoceras* is merely a large representative of *Girtyoceras mesleri-*

[2] Not *Sagitticeras* Buckman, 1920.

EXPLANATION OF PLATE 46

FIGS. *1–13*—*Goniatites kentuckiensis* Miller. Seven hypotypes from the Mississippian Meramec series of Rockcastle County, Kentucky, All belong to Princeton University, and, with the exception of fig. *11* which is ×2, all illustrations are ×1. *4–6*, Show the internal suture of and outer volution of the conch. *11*, An enlargement showing the external ornamentation on the ventral portion of the test of a specimen some 40 mm. in diameter. (p. 361)

anum, the genotype of *Girtyoceras*—the originals of both came from the Caney shale of the same general area in Oklahoma The genotype of *Sagittoceras* is strikingly similar to that of *Girtyoceras* and the two forms are at least specifically related. Thus both *Dryochoceras* and *Sagittoceras* are to be suppressed as synonyms of *Girtyoceras*, which has priority.

In America, the genus *Girtyoceras* is known to be represented in the Caney shale of Oklahoma, the Barnett and Helms formations of Texas, the Floyd shale of Georgia, and the Upper Mississippian of eastern Kenrucky. In northern England it ranges through Bisat's *Beyrichoceras* (B) and *Posidonomya* (P_1 and P_2) zones of the middle and upper Viséan, and in continental Europe it occurs at various localities in beds of comparable age (and possibly in the lower Namurian).

Girtyoceras is closely related to *Eumorphoceras*, which however is characterized by a flattened venter, prominent lateral ribs, and longitudinal ventro-lateral grooves. Typical *Girtyoceras* lacks all of these features, but nevertheless there is more or less gradation between these two genera. *Girtyoceras coronula* (Roemer) and *G. limatus* (Miller and Faber) are intermediate forms.

Girtyoceras is also related to *Gonioglyphioceras* and *Gonioloboceras*. All three have lenticular conchs and similarly shaped sutures, though in *Gonioglyphioceras* there is a tendency for the lateral lobes to be rounded. Large mature forms with rounded venters are referred to *Gonioloboceras* and similar forms with retuse venters are placed in *Gonioglyphioceras*. However, the ventral groove of *Gonioglyphioceras* is confied to the test and does not appear on the internal mold. Only the internal mold of the genotype of *Gonioloboceras* is known.

GIRTYOCERAS LIMATUM
(Miller and Faber)
Plate 47, figures 6–12

Goniatites limatus MILLER and FABER, *1892*, Cincinnati Soc. Nat. History, Jour., vol. 14, pp. 166–167, pl. 6, figs. 8, 9.
Goniatites leviculus MILLER and FABER, *1892*, Cincinnati Soc. Nat. History, Jour., vol. 14, p. 167, pl. 6, figs. 10, 11.
Glyphioceras? leviculum SMITH, *1903*, U. S. Geol. Survey Mon. 42, p. 65, pl. 8, figs.10, 11.
Goniloboceras? limatum SMITH, *1903*, U. S. Geol. Survey Mon. 42, p. 124, pl. 8, figs. 8, 9.
?Eumorphoceras bisulcatum GIRTY, *1911*, U. S. Geol. Survey Bull. 439, pp. 103–104, pl. 14, fig. 4.
?Adelphoceras meslerianum? GIRTY, *1911*, U. S. Geol. Survey Bull. 439, pp. 104–105, pl. 14, figs. 5–5b.
?Sagittoceras coronula [part] SCHMIDT, *1929*, Tierische Leitfossilien des Karbon, Gürich's Leitfossilien, Lief. 6, p. 69, pl. 18, fig. 18 [not figs. 16, 17, 19].
Milleroceras limatum MILLER, *1932*, Jour. Paleontology, vol. 6, p. 70.
Milleroceras leviculum MILLER, *1932*, Jour. Paleontology, vol. 6, p. 70.
Sagittoceras? limatum PLUMMER and SCOTT, *1937*, Texas Univ. Bull. 3701, p. 325.

Conch sublenticular with rounded venter during early growth-stages but angular venter at full maturity. In the outer volution of the holotype the shape of the venter changes gradually from rounded to subangular. Preserved portion of holotype, which consists of about seven volutions and is entirely septate, is about 20 mm. in diameter. Near adoral end of holotype conch is about 7 mm. wide and 10½ mm. high, and corresponding measurements at adoral end of penultimate volution are about 4 mm. and 4 mm.

Umbilicus moderate in size. Umbilicus of outer volution of holotype is slightly but distinctly smaller than that of preceding volution. However, except in the outer one and one-half volutions of the holotype, the umbilicus increases in size.

All available specimens are interanal molds and test is not represented on any of them. Nevertheless, there are traces of some eight of nine sinuous transverse constrictions preserved on at least the mature volutions of the conch. On the adoral half of the outer volution of the holotype, the largest specimen known, the constrictions are reduced to transverse grooves located on the umbilical half of the lateral zones of the conch. On the outer volutions of at least some of the type specimens there is a shallow inconspicuous rounded longitudinal groove on each of the ventro-lateral zones of the conch.

At maturity each suture forms a very large prominently divided ventral lobe and on either side of it a narrowly rounded first lateral saddle, an angular V-shaped first lateral lobe, and a broad rounded saddle which extends to an angular lobe on the umbilical wall. The internal suture consists of

three narrow lobes grouped near the dorsum.

Remarks.—Altogether there are available to us for study seven representatives of this species: the holotype, the three type specimens of "*Goniatites leviculus*," amd three topotypes. Only one of the three type specimens of "*G. leviculus*," the largest one, merits figuring (pl. 47, figs. 7–9). It is about 14½ mm. in diameter, and near its adoral end the conch is about 6½ mm. high and 6 mm. wide. Its umbilicus measures almost

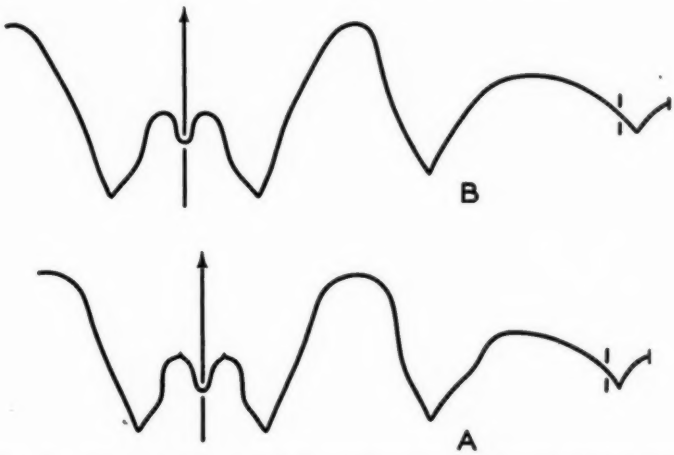


FIG. 8.—External sutures of (A) *Girtyoceras meslerianum* (Girty) and (B) *G. limatum* (Miller and Faber), both ×6. A is based on the topotype represented by figures 3–5 on plate 47, at a diameter of about 16 mm. B is based on the holotype at a diameter of about 18 mm.

5 mm. in diameter and has started to decrease in size. Although this specimen is very similar to the holotype and is almost certainly conspecific with it, it should be noted that the width of its conch and the diameter of its umbilicus are both about fifteen per cent greater than the corresponding dimensions of the holotype at the same diameter. The three topotypes are all rather small and poorly preserved. They show a slight amount of variation but are almost certainly conspecific with the holotype.

Girtyoceras limatum is closely similar to the genotype, *G. meslerianum* (Girty) (pl. 47, figs. 1–5) but differs in that it bears slight ventro-lateral grooves and more numerous transverse constrictions. *G. meslerianum* was originally described from the Caney shale of Oklahoma, but specimens that appear to be conspecific have been referred to it from various localities in Europe. *G. coronula* (Roemer), which is very widespread and is characteristic of the uppermost Viséan, is particularly close to *G. limatum*. It also bears ventro-lateral grooves and numerous transverse constrictions.

The poorly preserved specimens from the Moorefield shale of Arkansas which in 1911 Girty figured as *Eumorphoceras bisulcatum* and *Adelphoceras meslerianum?* are probably conspecific. They have certain of the characteristics of *Eumorphoceras* and are intermediate between typical representatives of that genus and typical *Girtyoceras*. They are thus close to the species under consideration, *Girtyoceras limatum*, and may be referable to it. Schmidt in 1929 reproduced one of Girty's illustrations and referred it to *G. coronula*, which is at least closely related to *G. limatum*.

Occurrence.—The holotype of this species and the type specimens of *G. leviculum* came from the Mississippian near Crab Orchard, Rockcastle County, Kentucky; also we have three additional specimens from the same general locality. Both of the specimens from the Moorefield shale that we are referring with question to this species came from about 5 miles north of Moorefield, Arkansas.

Types.—Walker Museum of the University of Chicago, 8753 (holotype) and

8752 (the 3 type specimens of "*Goniatites leviculus*"); and paleontological collections of Princeton University (3 topotypes).

DIMORPHOCERAS EDWINI
Miller and Furnish, n. sp.

This species is being based on two specimens, the largest of which, the holotype, is about 8 mm. in diameter. Both of the type specimens are only moderately well preserved, and both are septate throughout.

Conch is subglobular and whorls are distinctly depressed dorso-ventrally. Umbilicus very small and almost closed. Neither of the type specimens, internal molds, shows any trace of surface ornamentation. Presumably, as in other representatives of this genus, the test is marked by only fine sinuous growth-lines.

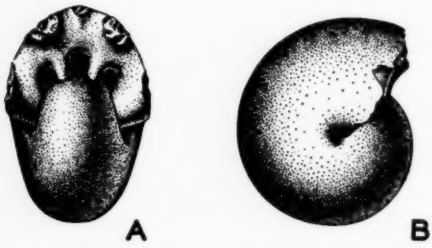


FIG. 9.—The holotype of *Dimorphoceras edwini* Miller and Furnish, n. sp., ×4.

Each external suture forms a large prominently divided ventral lobe and on either side of it a rounded first lateral saddle, a bifid first lateral lobe, and a broadly rounded second lateral saddle which extends to the lobe on the umbilical wall (text fig. 10). The major subdivisions of the ventral lobe are straight-sided and are asymmetrically bifid. They are about as wide as the median secondary saddle that separates them. The internal sutures form three narrow lobes, all of which are grouped near the dorsum.

Remarks.—All of the closely related representatives of this genus are small, and therefore the holotype of *D. edwini* may be fully mature in spite of its small size. It is very closely related to *D. discrepans* (Brown), which is widespread in the Viséan and Namurian of western Europe. Although in typical representatives of that species the first lateral saddles of the sutures are narrower than are those of the holotype of *D. edwini*, the two may prove to be indistinguishable. We have a specimen (State Univ. Iowa, 1408) from the Caney shale near Ada, Oklahoma, that appears to be referable to *D. discrepans*, and it has a much narrower first lateral saddle and more prominently digitate lobes. It was found in association with *Goniatites* and *Girtyoceras*. The discovery of this specimen in the Caney indicates that Bisat (1924, p. 87) was probably correct when he suggested that *Trizonoceras lepidum* Girty of the Caney is "strikingly similar" to *D. discrepans*, and the two may be conspecific.

Occurrence.—Meramec series of Rockcastle County, Kentucky.

Types.—Paleontological collections of Princeton University (holotype) and Yale Peabody Museum (paratype).

II. MISSISSIPPIAN (MERAMEC) AMMONOIDS FROM NORTHWESTERN GEORGIA

Near the southern limit of the Paleozoic outcrops of the Appalachians, a few ammonoids were collected some 25 years ago from the Floyd shale and deposited in the U. S. National Museum. These were recently called to our attention by Dr. G. A. Cooper. Although the Late Paleozoic rocks of this general vicinity have received considerable attention, no ammonoids have been recorded from them previously. Only two genera, *Girtyoceras* and *Lyrogoniatites*, n. gen., are represented by the available ma-

FIG. 10.—Diagrammatic representation of one of the adoral sutures of the holotype of *Dimorphoceras edwini* Miller and Furnish, n. sp., at a diameter of about 8 mm., ×10.

terial, but fortunately they are fairly diagnostic and indicate that the fauna is of Meramec age.

The nearest localities that have yielded related ammonoids are in eastern Kentucky and eastern Arkansas, more than 200 miles to the north and the west. The ammonoid fauna represented is widespread but is best known from the Caney shale of Oklahoma and from the upper *Posidonomya* (Bisat's P_2) zone in the upper Viséan of western Europe.

GIRTYOCERAS MESLERIANUM (Girty)
Plate 48, figures 1–3

Adelophoceras meslerianum GIRTY, *1909*, U. S. Geol. Survey, Bull. 377, pp. 66–67, pl. 12, figs. 1–3c; WEDEKIND, *1914*, Mitt. Mus. Stadt Essen, Heft 1, p. 11; PLUMMER and SCOTT, *1937*, Texas Univ., Bull. 3701, p. 174, pl. 38, figs. 17, 18.

Girtyoceras meslerianum WEDEKIND, *1918*, Palaeontographica, Bd. 62, p. 140; BRÜNING, *1923*, Geol. Archiv, Bd. 1, Heft 5, p. 265; MILLER, *1934*, Am. Jour. Sci., 5th ser., vol. 28, p. 33.

Beyrichoceras meslerianum BISAT, *1924*, Yorkshire Geol. Soc., Proc., n. ser., vol. 20, p. 72.

Dryochoceras brainerdi MORGAN, *1924*, [Oklahoma] Bur. Geol., Bull. 2, pp. 185–186, pl. 52, figs. 7–7b.

Homoceras meslerianum SCHMIDT, *1925*, Preuss. Geol. Landesanstalt, Jahrb., Bd. 45, pp. 676, 581, pl. 21, fig. 18, pl. 24, figs. 24–26.

Sagittoceras meslerianum BISAT, *1928*, C. R. Cong. l'avanc. études Stratigr. Carbon; Heerlen, 1927, p. 125; SCHMIDT, *1929*, Tierische Leitfossilien des Karbon, Gürich's Leitfossilien, Lief. 6, p. 69, pl. 18, figs. 20–22; KOBOLD, *1932*, Preuss. geol. Landesanstalt, Jahrb., Bd. 53, pp. 505–506; BISAT, *1933*, Geol. Assoc., Proc., vol. 44, p. 256; —, *1936*, Internat. Geol. Cong., Rept. 16th sess., vol. 1, p. 533; MOORE, *1936*, Manchester Geol. Assoc., Jour., vol. 1, p. 177.

Sagittoceras brainerdi MILLER, *1934*, Am. Jour. Sci., 5th ser., vol. 28, pp. 31, 32; MOORE, *1936*, Manchester Geol. Assoc., Jour., vol. 1, p. 177.

During adolescence and early maturity, conch is rounded ventrally and is subdiscoidal, but at full maturity it becomes angular ventrally and therefore lenticular. Conch is evolute during early growth-stages but becomes involute, and at full maturity umbilicus is moderately small. Large individuals attain a diameter of at least 125 mm.

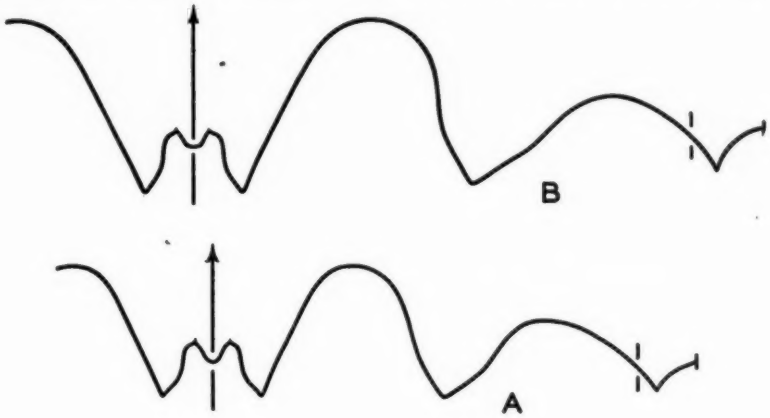


FIG. 11.—Sutures of *Girtyoceras meslerianum* (Girty), both ×12. A is based on a specimen (State Univ. Iowa, 1411; pl. 47, figs. 1, 2) from the lower Caney shale south of Ada, Pontotoc County, Oklahoma, and it represents the sutures at a diameter of about 10 mm. B is based on a specimen (U. S. Nat. Mus., 60600) from the Floyd shale north of Rome, Floyd County, Georgia, and it represents the sutures at a diameter of about 11 mm.

Growth-lines form a deep ventral sinus, rather prominent ventro-lateral salients, broadly rounded lateral sinuses, and similar dorso-lateral salients. During early maturity the conch bears transverse constrictions which are parallel to the growth-lines. These constrictions become less prominent during ontogenetic development and are obsolete at full maturity.

During early maturity, at a diameter of some 7 mm., each suture forms a relatively narrow subequally trifid ventral lobe and a

narrowly rounded first lateral lobe. By the time the conch has attained a diameter of 10 mm. (text fig. 11), the ventral lobe has become relatively broad and prominently subdivided and the first lateral lobe has become angular. With further development the prongs of the ventral lobe tend to become attenuate and the first lateral saddle becomes narrowly rounded.

Remarks.—The Georgia specimens that we are referring to this species represent early mature portions of the phragmacone, and all are less than 15 mm. in diameter. Girty's type specimens from Oklahoma are also relatively small, but large individuals of the species are known from the same general horizon and locality. One of these was described by Morgan in 1924 as *Dryochoceras brainerdi.*

Various European paleontologists have referred specimens from their continent to this species. For the most part these seem to be very similar to the American types, but as has been noted by Moore, a direct comparison makes it clear that at least some of the English specimens are wider than the American individuals. *Girtyoceras acutum* (Hind), the genotype of *Sagittoceras*, and *G. discus* (Roemer) are closely similar to *G. meslerianum* and may be conspecific with it.

Occurrence.—The type specimens of this species came from the *Goniatites* zone of the lower Caney shale of Oklahoma, and conspecific specimens are stated to occur in the upper Viséan (Bisat's P_2 zone) at various localities in western Europe. The Georgia specimens, which are pyritized and came from a black shale matrix, were collected in 1913 from "C. H. Land's well, Lot 286, 24th Dist., 3d Sec., Floyd County, Georgia, about 5½ miles north of Rome."

Hypotypes.—U. S. National Museum, 60600 (4 specimens from Georgia).

Genus LYROGONIATITES
Miller and Furnish, n. gen.

Conch subglobular, whorls broadly rounded ventrally, and umbilicus moderately large. Surface marked by prominent longitudinal lirae, moderately prominent growth-lines, and very prominent transverse constrictions. The growth-lines and the constrictions, which are parallel, are nearly straight and directly transverse, but they form shallow ventral and lateral sinuses. Sutures are of a simple goniatitid type, and each forms a moderate-sized divided ventral lobe, a V-shaped lateral lobe, and a lobe on the umbilical wall.

This genus is closely related to *Neoglyphioceras* Brüning but differs particularly in that the conch is subglobular rather than subdiscoidal and the umbilicus is relatively large. *Owenoceras*, which is also similar, has a gastrioceratid rather than a goniatitid type of suture and may not be closely related. *Entogonoceras* Plummer and Scott (1937, text fig. 88), a *nomen nudum*, is probably synonymous with *Lyrogoniatites.*

The new genus includes in addition to its genotype, *L. newsomi georgiensis* Miller and Furnish, n. var., the following forms: *Goniatites newsomi* Smith of the Moorefield of Arkansas, the Caney of Oklahoma, the Barnett and Helms of Texas, and the upper Viséan of western Europe and *G. entogonus* Gabb of the Barnett of Texas (pl. 48, figs. 17, 18).

LYROGONIATITES NEWSOMI GEORGIENSIS
Miller and Furnish, n. var.
Plate 48, figures 4–10

The holotype of this species (pl. 48, figs. 7–9) is well preserved but slightly distorted. It retains more than three-fourths of a volution of the living chamber and is about 25 mm. in diameter. Near its adoral end the conch is about 18 mm. wide. One of the smaller paratypes (pl. 48, figs. 4–6), which is septate throughout, is about 10 mm. in diameter, and near its adoral end it is slightly more than 8 mm. wide. The umbilical shoulders are fairly definite, and the umbilicus of the holotype attains a maximum diameter of about 9 mm.

The surface of the test is reticulate as it bears some 35–40 prominent longitudinal lirae and less conspicuous transverse growth-lines. The growth-lines form shallow ventral and lateral sinuses. Also, the conch bears prominent transverse constrictions, which are parallel to the growth-lines and number about three or four to the volution. These persist without apparent diminution on even the outer volution of the largest specimen known, the holotype.

As shown by text figure 12, each suture forms a relatively narrow divided ventral

lobe, a V-shaped first lateral lobe, and a lobe on the umbilical wall. The lateral saddles are broad and rounded.

Remarks.—This form appears to differ from the typical variety in that its whorls are lower and broader and therefore its conch is more nearly globular. *L. entogonus* (Gabb) is more widely umbilicate (pl. 48, figs. 17, 18).

Occurrence.—The type specimens of this variety, which are pyritized and came from a black shale matrix, were collected in 1913 from "C. H. Land's well, Lot 286, 24th Dist., 3d Sec., Floyd County, Georgia, about 5½ miles north of Rome."

Types.—U. S. National Museum, 60600 (holotype and 5 paratypes).

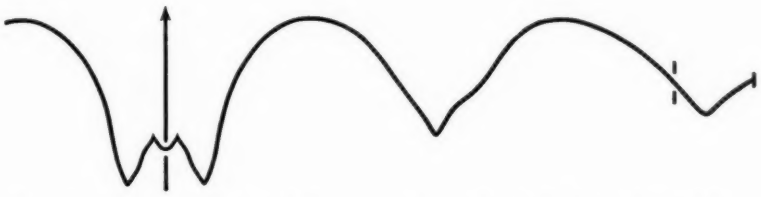


FIG. 12.—Suture of *Lyrogoniatites newsomi georgiensis* Miller and Furnish, n. var., ×8; based on the holotype at a diameter of about 15 mm.

III. A PRIMITIVE DARAELITID FROM THE MISSISSIPPIAN (MERAMEC) OF OKLAHOMA

Well preserved ammonoids are abundant in the Caney shale of Oklahoma, and the fauna has been ably described by Girty. Our collections from the lower portion of the formation contain a new species, *Epicanites loeblichi*, which was found in association with *Goniatites* s. s., *Girtyoceras*, *Dimorphoceras*, etc. *Epicanites* is a primitive member of the Daraelitidae which is widespread in the Late Paleozoic. Representatives of this family are known from numerous horizons and localities in the Pennsylvanian and the Permian of Texas and Oklahoma, but earlier forms have been found previously in only the Eastern Hemisphere.

Genus EPICANITES
Schindewolf, 1926

Paraprolecanites KARPINSKY [part ?], *1889*, Acad. Imp. Sci. St.-Pétersbourg, Mém., 7e sér., tome 37, no. 2, pp. 7–8; HAUG [part ?], *1898*, Soc. géol. France, Mém. Palaeontologie, tome 7, no. 18, pp. 51, 69; TSCHERNOW [part], *1907*, Soc. Imp. Nat. Moscou, Bull., n. sér., tome 20, pp. 372, 373; DOLLÉ [part], *1912*, Soc. géol. Nord. Ann., tome 41, pp. 254–256; SCHMIDT, *1925*, Preuss. geol. Landesanstalt, Jahrb., Bd. 45, p. 544; DELÉPINE, *1935*, Soc. géol. France, Bull., 5e sér., tome 5, pp. 175, 176; BISAT, *1936*, Internat. Geol. Cong., Rept. 16th sess., vol. 1, p. 536; MOORE, *1936*, Manchester Geol. Assoc., Jour., vol. 1, pp. 187–188. [Not PLUMMER and SCOTT, *1937*, Texas Univ., Bull. 3701, pp. 50–52.]

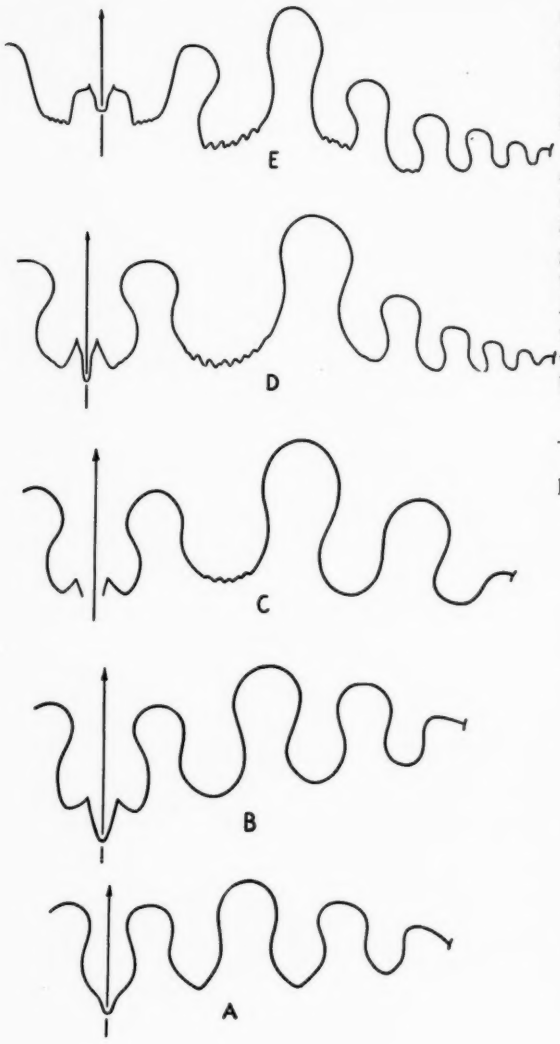
Prodaraelites TSCHERNOW, *1907*, Soc. Imp. Nat. Moscou, Bull., n. sér., tome 20, pp. 392–397.

Epicanites SCHINDEWOLF, *1926*, Senckenbergiana, Bd. 8, pp. 75, 94; —, *1934*, Gesell. Wiss. Göttingen, Math.-phys. Kl., Abh., Folge 3, Heft 10, p. 180.

Daraelites [part] FROMAGET, *1931*, Soc. géol. France, Bull., 5e sér., tome 1, pp. 659–661; KOBOLD, *1932*, Preuss. geol. Landesanstalt, Jahrb., Bd. 53, p. 506; DELÉPINE, *1935*, Soc. géol. France, Bull., 5e sér., tome 5, pp. 174–175.

Praedaraelites SCHINDEWOLF, *1934*, Gesell. Wiss. Göttingen., Math.-phys. Kl., Abh., Folge 3, pp. 176–181; PLUMMER and SCOTT, *1937*, Texas Univ., Bull. 3701, pp. 98–99.

When Schindewolf established this genus in 1926, he designated as genotype, *Paraprolecanites sandbergeri* Schmidt (=*P. mixolobus* Dollé, but not *Goniatites mixolobus* Phillips, G. and F. Sandberger, or Karpinsky) of the Viséan of Algeria. Dollé's photographic illustrations of the type specimens of this species show that his suture drawing is not accurate in detail. Each external suture consists of a short broad trifid ventral lobe that is contracted adorally, and on either side of it a broad rounded first lateral lobe, a narrower second lateral lobe which is curved toward the umbilicus, a smaller third lateral lobe, and probably a small lobe on the umbilical seam. The second lateral saddle is noticeably high as in other members of the Daraelitidae. The conch is subdiscoidal, the whorls are rounded ventrally and laterally and only



slightly impressed dorsally, and the umbilicus is large. The surface of the test is marked by fine inconspicuous growth-lines which form a ventral sinus, lateral salients, and dorso-lateral sinuses.

The genotype of *Praedaraelites*, *Daraelites culmiensis* Kobold of the upper Viséan of Germany, is very similar to *Epicanites sandbergeri*. When Schindewolf established the genus *Praedaraelites* he stated that its genotype is more advanced than is that of *Epicanites*. However, he considered that these two genera might be synonymous, and we are convinced that they should not be differentiated. Kobold's illustrations of

FIG. 13.—Mature sutures of Prolecanitidae and Daraelitidae

(A) *Prolecanites discoides* Foord and Crick? at a diameter of about 12 mm., ×7; based on a specimen (State Univ. Iowa, 1412) from the *Beyrichoceras* zone in the middle Viséan at Cowdale Clough, northern England.

(B) *Epicanites sandbergeri* (Schmidt), the genotype of *Epicanites*, at a diameter of some 10 mm., enlarged; based on a syntype from the upper Viséan of Algeria. (Adapted from Dollé.)

(C) *Epicanites culmiensis* (Kobold), the genotype of "*Praedaraelites*," about ×4; based on the holotype from the upper Viséan of Germany. (Adapted from Kobold.)

(D) *Daraelites* (*Boesites*) *texanus* Böse, the type species of *Boesites*, at a diameter of about 14 mm., ×7; based on a topotype (Yale Peabody Museum, 16777) from the Gaptank formation of west Texas.

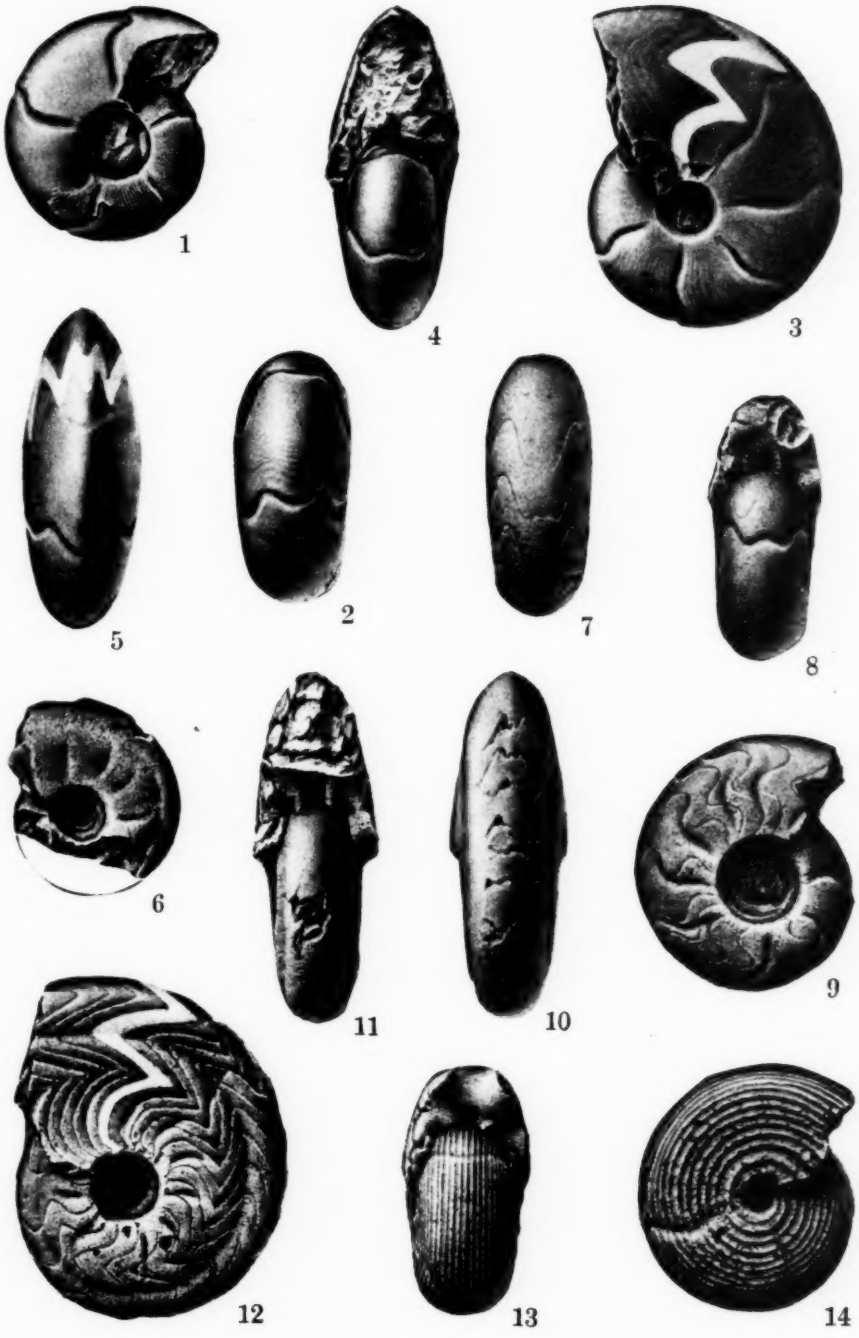
(E) *Daraelites meeki* Gemmellaro, the genotype of *Daraelites*, at a diameter of about 25 mm., ×4; based on a topotype (Yale Peabody Museum, 15214) from the Middle Permian of Sicily.

EXPLANATION OF PLATE 47

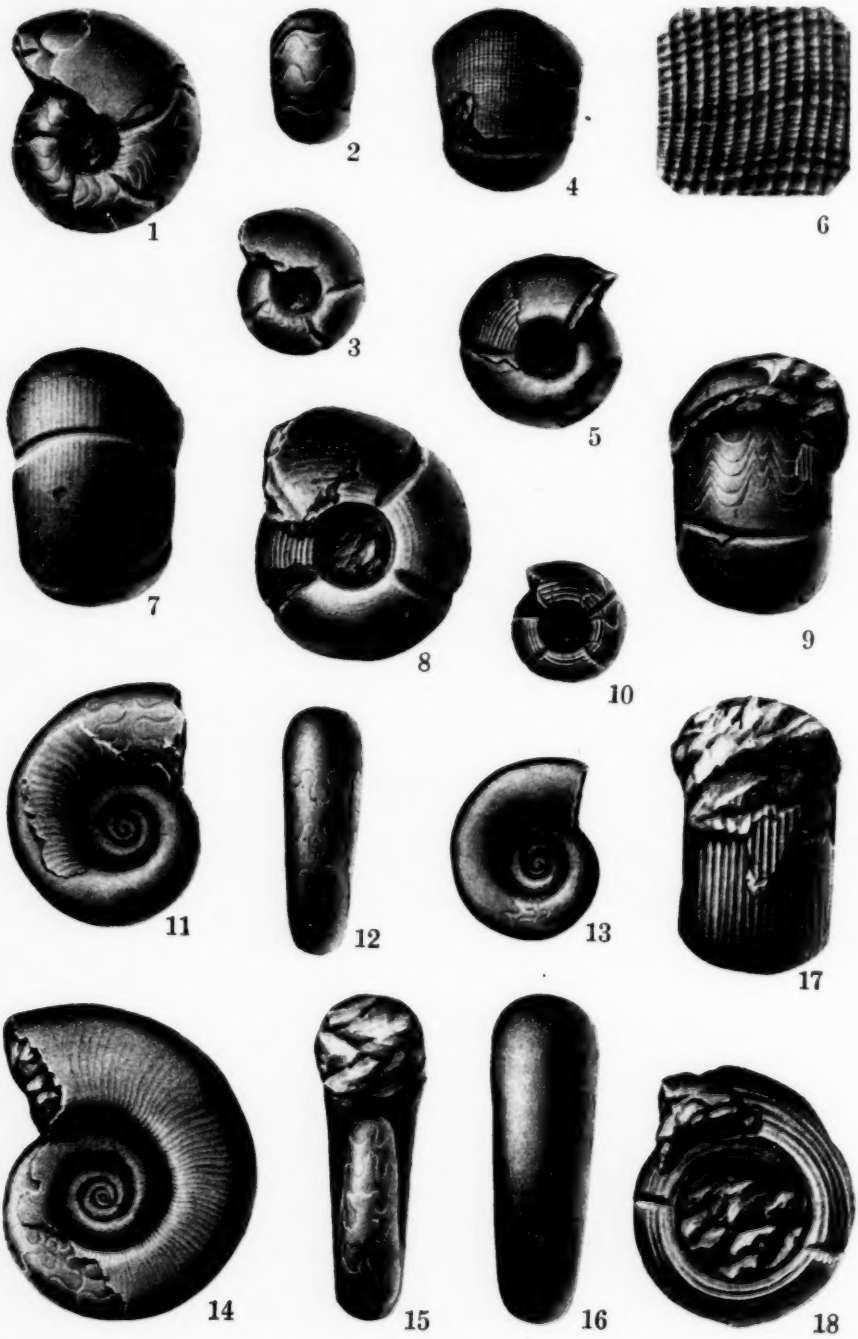
FIGS. *1–5*—*Girtyoceras meslerianum* (Girty). Two representative specimens, ×2, of the genotype of *Girtyoceras*, from the lower Caney shale south of Ada, Pontotoc County, Oklahoma (State Univ. Iowa collections, 1411).

6–12—*Girtyoceras limatum* (Miller and Faber). Three representatives, ×2, from the Meramec series of Rockcastle County, Kentucky. *10–12*, The holotype (Walker Museum, 8753); *7–9*, one of the types of "*Goniatites leviculus*" (Walker Museum, 8752); and *6*, a topotype (Princeton University collections). (p. 364)

13, 14—*Neoglyphioceras subcirculare* (Miller). Two typical representatives, ×2, from the same horizon and locality as the preceding (Princeton University collections). (p. 360)



Miller and Furnish, Carboniferous Ammonoids



Miller and Furnish, Carboniferous Ammonoids

"Daraelites" culmiensis show the first lateral lobe of the sutures to be denticulate, whereas that of *Epicanites sandbergeri* appears to be simple and rounded. However, our experience has gone to show that such fine denticulations are largely a matter of preservation and interpretation and therefore can not be accorded much taxonomic value.

When Karpinsky proposed the genus *Paraprolecanites*, he referred to it without question only Sandbergers' figures 6 on their plate 9 of 1851. One of these two figures is a suture drawing that, as has been noted by both Schmidt and Schindewolf, is based to a large extent on the specimen represented by Sandbergers' figure 13 on their plate 3 of the same publication. In order to remove ambiguity, we are designating the specimen on which these latter figures are based as the genotype of *Paraprolecanites*. Since it is also the genotype of *Prolecanites*, *Paraprolecanites* is to be suppressed as a synonym of *Prolecanites*, which has priority. Sandbergers' other figure 6 on their plate 9 represents a small fragment of the ventral portion of a phragmacone of a species which Schmidt and Schindewolf have agreed is referable to *Pronorites*, but the possibility of its belonging in *Epicanites* can hardly be excluded. Apparently, *Prodaraelites* Tschernow exists only as a concept and is therefore to be regarded as invalid.

Epicanites is similar to *Daraelites* and is more or less intermediate between that genus and *Prolecanites*. There is essentially complete gradation from the genotype of *Epicanites* to that of *Daraelites*, *D. meeki* Gemmellaro of the Middle Permian of Sicily. It seems to us that there is a generic or subgeneric step between these two genotypes, and we here propose the name *Boesites*, as a subgenus of *Daraelites*, for the intermediate forms and designate *Daraelites texanus* Böse of the Upper Pennsylvanian of Texas and Oklahoma as the genotype.

From both a morphologic and a stratigraphic point of view, it appears that *Epicanites* arose from *Prolecanites*, and that it then gave rise to *Daraelites* through *Boesites*. In *Prolecanites* (text fig. 13A) the ventral lobe of the sutures is tongue-shaped and is undivided. The lateral lobes, which are few in number, tend to be tongue-shaped and to be subequal in size. In *Epicanites* (text figs. 13B, 13C) the ventral lobe is trifid and, though fairly broad, is contracted adorally. The first lateral lobe is distinctly broader than the other lateral lobes and in at least some cases is finely denticulate at full maturity. The sutures of *Boesites* (text fig. 13D) form a relatively broad and strongly trifid ventral lobe, a very broad first lateral lobe, and several smaller lateral lobes. The first lateral lobe is finely denticulate, and the second lateral lobe and the lateral subdivisions of the ventral lobe may be incipiently so. Typical *Daraelites* (text fig. 13E) differs in that the ventral lobe is very broad and is not contracted adorally, the first lateral lobe is relatively narrow, and denticulation is characteristic of the second lateral lobe and may be extended to the third.

EXPLANATION OF PLATE 48

FIGS. *1–3—Girtyoceras meslerianum* (Girty). Two small representatives of this species, ×2½; both from the Floyd shale near Rome, Georgia. (p. 367)

4–10—Lyrogoniatites newsomi georgiensis Miller and Furnish, n. var. Two views, ×2½, and an enlargement, ×8, of ventral portion of the test of a paratype (figs. 4–6); three views, ×1½, of the holotype (figs. 7–9); and lateral view, ×6, of a small paratype (fig. 10)—all from the Floyd shale near Rome, Georgia. (p. 368)

11, 12—Prolecanites discoides, Foord and Crick? A specimen (State Univ. Iowa, 1412) from the *Beyrichoceras* zone of the middle Viséan in Cowdale Clough, northern England, ×5. (p. 373)

13–16—Epicanites loeblichi Miller and Furnish, n. sp. The paratype and three views of the holotype, ×5; both from the lower Caney shale south of Ada, Oklahoma (p. 372)

17, 18—Lyrogoniatites entogonus (Gabb). Two views, ×½, of a hypotype from the Barnett shale about 5½ miles southwest of Lampasas, Lampasas County, Texas. (After Plummer and Scott.) (p. 368)

As interpreted by us, *Epicanites* includes besides its genotype, *E. sandbergeri* of the upper Viséan of Algeria and possibly northern England, the following forms: *Daraelites culmiensis* of the upper Viséan of Germany, *D. praecursor* of the lower Namurian of French Indo-China, *D. praecursor pyrenaicus* of the upper Viséan of the Pyrenees, *Praedaraelites* sp. Schindewolf (1934, pp. 180–181, pl. 6, fig. 6) of the lower Namurian of Menorca, and the form described below as *E. loeblichi* from the Caney of Oklahoma. The genus thus appears to be world-wide in its distribution but stratigraphically to be confined to beds of upper Viséan and lower Namurian age.

Boesites includes *Daraelites texanus* of the Gaptank of west Texas, the Graham of north-central Texas, and the Nellie Bly of Oklahoma (genotype), *D. scotti* of the Smithwick of north-central Texas, and *D. girtyi* of the Wewoka of Oklahoma. It is thus not known to occur outside of the Pennsylvanian of the United States, but stratigraphically it can be said to range through most of that system, that is, from the upper Bend to the lower Cisco.

We are leaving in *Daraelites* s. s. the following forms: *D. meeki* of the Sosio beds of Sicily, *D. elegans* of the Artinskian of the Urals, *D. submeeki* of the Bitauni beds of Timor, *D. kingi* of the Wolfcamp of west Texas, and *D. leonardensis* of the Leonard of west Texas. Typical representatives of the genus are then known to occur in only the Permian, but they range from near the base of that system well up into the mid-portion of it, that is, from the Wolfcamp up into the Word equivalent.

EPICANITES LOEBLICHI
Miller and Furnish, n. sp.
Plate 48, figures 13–16

Conch is subdiscoidal and evolute. Whorls are rounded ventrally, broadly rounded laterally and slightly impressed dorsally. The holotype, the larger of the two type specimens, consists of about four and one-half volutions and may be essentially complete. It is about 9 mm. in diameter, and its maximum width measures slightly more than 3 mm. The adoral half-volution of this specimen represents living chamber, and at least this portion of the conch is slightly higher than wide.

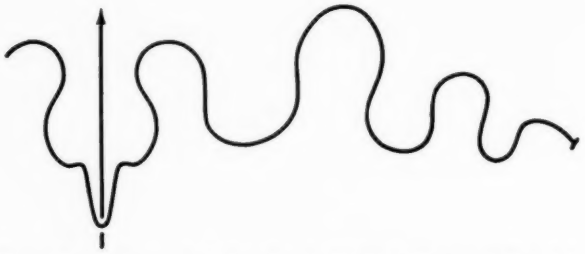


FIG. 14.—Suture of *Epicanites loeblichi* Miller and Furnish, n. sp., ×25; based on the holotype at a diameter of about 6 mm.

The surface ornamentation of the test consists of inconspicuous growth-lines which are not strongly sinuous but which form a very broad rounded ventral sinus, low rounded lateral salients, and smaller sinuses in the region of the umbilicus. There appear to be one or two slight transverse constrictions on the first volution of the conch.

As shown by text figure 14, each suture consists of a trifid ventral lobe and on either side of it a broad rounded first lateral lobe and two or possibly three smaller rounded lateral lobes. Both of the type specimens are small, and the maximum diameter of the phragmacone represented is only about 6 mm. Probably, as in some other representatives of this genus, the conch attained a larger size, the sutures developed more lateral lobes, and the first lateral lobe became denticulate.

Remarks.—This species resembles closely the genotype, *E. sandbergeri*, and may even be conspecific with it. The figured specimen

of that species is larger than the holotype of *E. loeblichi*, but its sutures are comparable (compare text figs. 13B and 14). *E. praecursor* has more advanced sutures than the form under consideration, but the type specimens of that species are much larger.

Prolecanites of the type of *P. discoides* (pl. 48, figs. 11, 12) occurs in Bisat's *Beyrichoceras* (B) and lower *Posidonomya* (P_1) zones of the middle and upper Viséan. Advanced representatives of *Prolecanites* have inflated ventral lobes, and they more or less grade into *Epicanites*, which occurs in the upper *Posidonomya* zone (P_2) of the upper Viséan.

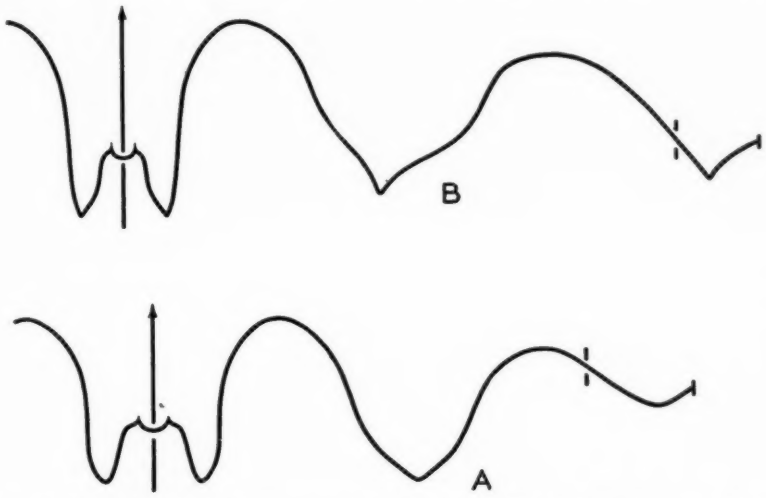


FIG. 15.—Sutures of (A) *Cravenoceras? nevadense* and (B) *C. hesperium*. A, which is ×14, is based on the specimens represented by figures 9–11 on plate 49, and it portrays the sutures at a diameter of about 7 mm. B, which is ×7, is based on the specimen represented by figures 7, 8 on plate 49, and it portrays the sutures at a diameter of about 17 mm.

Occurrence.—*Goniatites* zone of the lower Caney shale south of Ada, Pontotoc County, Oklahoma. The holotype was found by Alfred R. Loeblich in sec. 1, T. 1 N., R. 6 E., whereas the paratype came from near the east line of the NE. ¼, sec. 2, T. 2 N., R. 6 E.

Types.—State Univ. Iowa, 1410 (holotype) and 1409 (paratype).

IV. MIDDLE CARBONIFEROUS AMMONOIDS FROM EASTERN NEVADA

Two small collections of ammonoids from east-central Nevada were recently made available to us for study by Dr. G. A. Cooper. One of these consists entirely of representatives of a new species of *Cravenoceras*, *C. hesperium*, whereas the other is composed of questionable representatives of *Anthracoceras* and *Cravenoceras*, *A.? colubrellus* and *C.? nevadense*. *C. hesperium* is very closely similar to *C. leion* Bisat of the lower Namurian (E zone) of northern England, and it is now generally recognized that the lower Namurian of Europe is of about the same age as the Chester. Furthermore, typical *Cravenoceras* appears to be limited to the lower Namurian-Chester horizon. In the second Nevada collection, *Anthracoceras? colubrellus* is similar to an undescribed species in our collections from the Morrow (Brentwood limestone) of Oklahoma, and forms that are similar to *C.? nevadense* occur in both the Morrow and the upper Caney (Chester). Both Nevada collections came from the same general vicinity and from rocks of similar lithology, and it is probable that they represent the same fauna. In any case, the available evidence is insufficient to demonstrate a disparity in age if it exists.

"Goniatites" kingi Hall and Whitfield of the White Pine shale of central Nevada is probably referable to *Cravenoceras* and is

similar to *C. hesperium*. Presumably the beds that yielded the faunas under consideration are to be regarded as part of the White Pine formation, which according to Girty (1905, p. 12) is of about the same age as the Caney shale of Oklahoma. However, the ammonoid-bearing beds of the Snake Range can be referred with about equal propriety to the Chainman formation of Spencer (1917, pp. 26–27), which is in part at least equivalent to the White Pine. The type sections of these two formations appear to be about equidistant from the localities that yielded the ammonoids under consideration.

CRAVENOCERAS HESPERIUM
Miller and Furnish, n. sp.
Plate 49, figures 1–8

Conch globular (text fig. 16B). The largest of the syntypes (pl. 49, fig. 1), which appears to be almost complete, is about 34 mm. in diameter and near its adoral end is about 24 mm. wide, and its umbilicus is about 7 mm. in diameter. There is a certain amount of variation in the shape of the syntypes, extremes of which are illustrated by the specimens represented by figures 7, 8 and by figure 4 on plate 49. The former is about 19 mm. in diameter, it attains a width of about 11 mm., and its umbilicus is about 4 mm. in diameter; whereas comparable measurements for the latter are about 23 mm., 11 mm., and 3½ mm., respectively. The latter (fig. 14), in addition to having a relatively narrow conch and small umbilicus, has more numerous growth-lamellae (compare pl. 49, fig. 4, with figs. 5, 8). Also, the transverse constrictions appear to be less prominent on the narrowly umbilicated forms.

The growth-lines are nearly straight and directly transverse, but they form slight salients just outside the umbilical shoulders. Transverse constrictions parallel to the growth-lines are present, but they are visible on only the internal mold.

The sutures form a narrow divided ventral lobe, a broad pointed V-shaped first lateral lobe, an angular lobe on the umbilical wall, and three narrow internal lobes. All of the saddles are rounded.

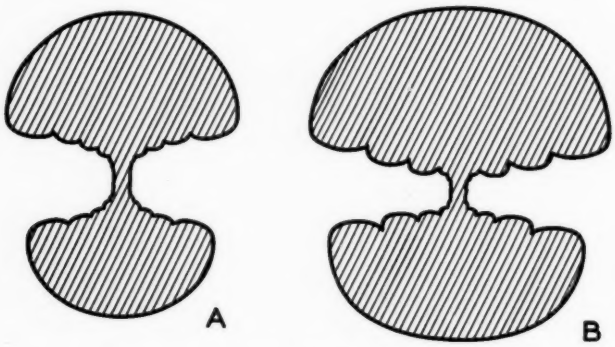


FIG. 16.—Cross sections of (A) *Cravenoceras? nevadense* and (B) *C. hesperium*, ×4.

Remarks.—This species is similar to the genotype of *Cravenoceras*, *C. malhamense* but differs in that its umbilicus is considerably smaller. It is perhaps most closely re-

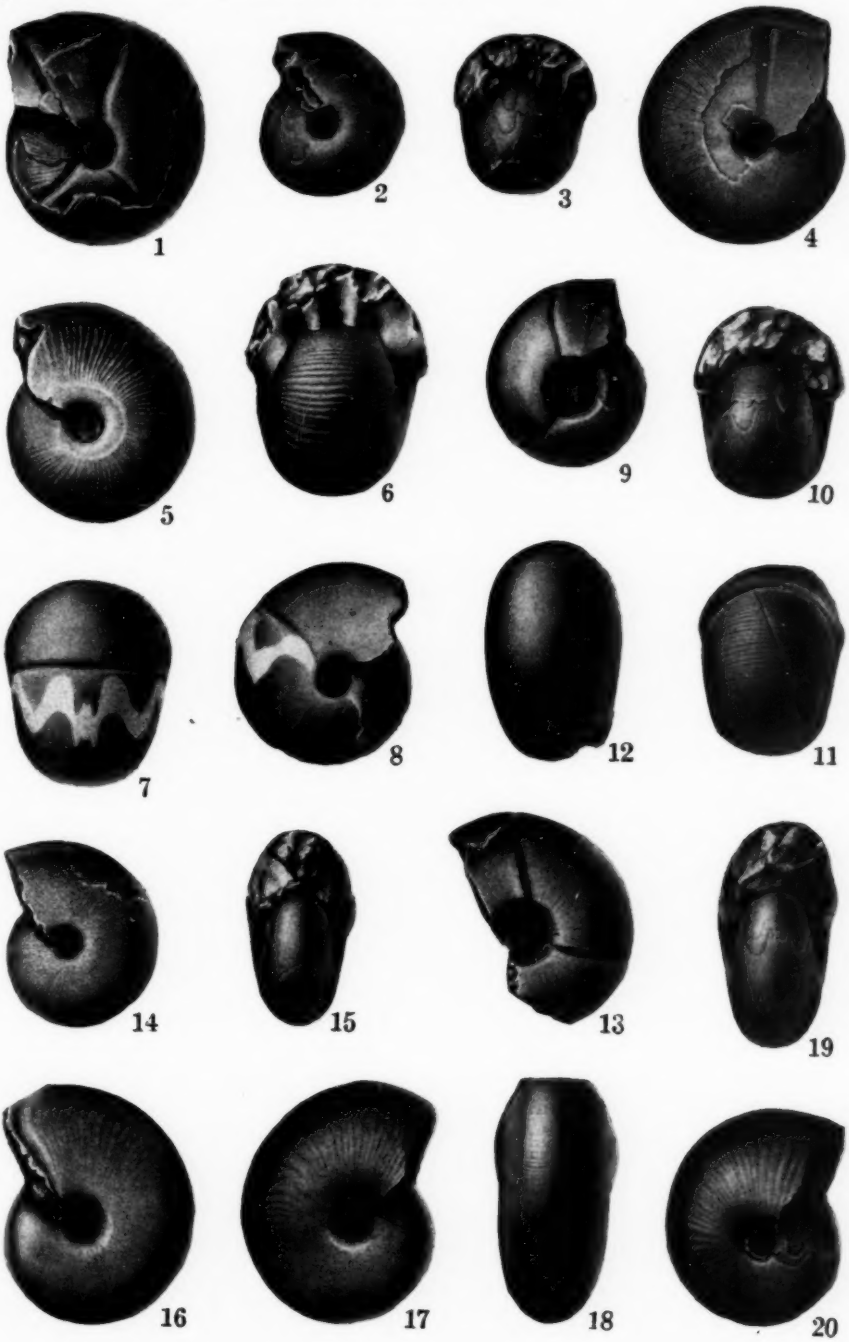
EXPLANATION OF PLATE 49

All specimens illustrated on this plate are from the Middle Carboniferous of east-central Nevada, and all are deposited in the U. S. National Museum.

FIGS. *1–8—Cravenoceras hesperium* Miller and Furnish, n. sp. Five of the syntypes. Figure 1 is ×1; figures 2, 3 are ×2½; and figures 4–8 are ×1½. (p. 374)

9–13—Cravenoceras? nevadense Miller and Furnish, n. sp. Two of the syntypes. Figures 9–11 are ×2½; and figures 12, 13 are ×1½. (p. 375)

14–20—Anthracoceras? colubrellus Miller and Furnish, n. sp. Three of the syntypes, all ×2½. (p. 376)



Miller and Furnish, Carboniferous Ammonoids

lated to *C. leion* and differs materially from it only in that the lateral lobes of its sutures are relatively broad. *"Gastrioceras" richardsonianum* and *"Goniatites" incisum*, both of which are of Chester age, resemble *C. hesperium*, but the ventral lobe of their sutures is relatively broad and they are more or less intermediate between typical *Homoceras* and typical *Cravenoceras*. *"Goniatites" kingi* is probably congeneric with *C. hesperium* but it has a larger umbilicus and somewhat different sutures.

some 13 mm. The maximum diameter of umbilicus of this specimen is about 6 mm. The inner whorls seem to be more nearly globular than the outer. The growth-lines are moderately prominent and are nearly straight and directly transverse, but they form slight ventral salients. There are faint longitudinal lirae near the umbilical shoulders. The conch bears transverse constrictions, which number two or three to the volution and are parallel to the growth-lines.

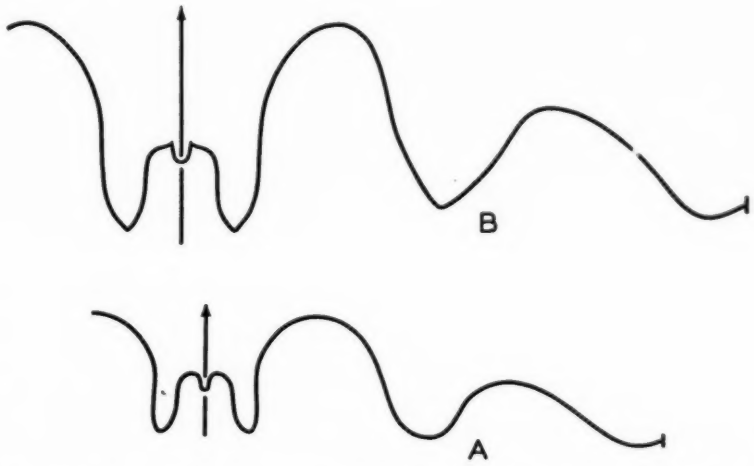


FIG. 17.—Sutures of *Anthracoceras? colubrellus* and *A.?* sp. A, which is ×12½, is based on a specimen (pl. 49, figs. 19, 20) from the southern portion of the Snake Range in easternmost Nevada, and it represents the sutures at a diameter of about 7½ mm. B, which is ×11, is based on a specimen (State Univ. Iowa, 1413) from the Brentwood limestone member of the Morrow near Lyons, Oklahoma, and it represents the sutures at a diameter of about 11 mm.

Occurrence.—The syntypes of this species were collected by J. M. Fox in Cave Valley some 35 miles west of Shoshone, Nevada, and they were deposited in the U. S. National Museum in 1923. The matrix in which they occur is a black shale or shaly limestone.

Syntypes.—U. S. National Museum (some 25 specimens).

CRAVENOCERAS? NEVADENSE
Miller and Furnish, n. sp.
Plate 49, figures 9–13

The largest of the syntypes (pl. 49, figs. 12, 13), the outer volution of which appears to represent living chamber, is about 20 mm. in diameter, and it attains a width of

The early mature sutures (text fig. 15A) consist of a divided ventral lobe, a broad V-shaped first lateral lobe, and a lobe on the umbilical wall. The saddles are rounded.

Remarks.—This species differs from *C. hesperium* in that it has a larger umbilicus and the ventral lobe of its sutures is broader. It resembles the form from the Caney shale of Oklahoma that Girty called *"Gastrioceras" richardsonianum*, but that species is more nearly globular and has a smaller umbilicus. Similar forms are known from the Namurian of Europe and are referred to *Cravenoceras* and *Homoceras*. At least the early mature sutures of *C.? nevadense* are similar to those of *"Gastrioceras" welleri*

Smith of the Lower Pennsylvanian Cherokee formation of Missouri.

Occurrence.—Black shale or shaly limestone near the southern end of the Snake Range in easternmost Nevada, in association with *Anthracoceras? colubrellus.*

Syntypes.—U. S. National Museum (4 specimens).

ANTHRACOCERAS? COLUBRELLUS
Miller and Furnish, n. sp.
Plate 49, figures 14–20

Conch subdiscoidal. The specimen represented by figures 16–18 on plate 49 attains a maximum diameter of about 13½ mm. and a maximum width of about 7 mm. Several of the syntypes are appreciably larger and attain a diameter of as much as 20 mm. The adoral end of one of these large specimens is crushed but it appears to portray an apertural constriction; the living chamber is about one volution in length. Conch is deeply impressed dorsally and umbilicus is very small. The growth-lines form a rather prominent rounded ventral sinus and rounded ventro-lateral salients, but they are nearly straight on the lateral portions of the conch.

Each suture (text fig. 17A) forms a prominently divided ventral lobe, a rounded first lateral lobe, a lobe that centers on the umbilical wall, and three narrow internal lobes. All the saddles are rounded.

Remarks.—*A.? colubrellus* is not closely similar to any named species, but we have an undescribed form from the Morrow of Oklahoma that appears to be related. Its general physiognomy and its sutures (compare text figs. 17A and 17B) resemble those of the species under consideration, but its conch bears transverse constrictions.

Occurrence.—Black shale or shaly limestone near the southern end of the Snake Range in easternmost Nevada, in association with *Cravenoceras? nevadense.*

Syntypes.—U. S. National Museum (25 specimens).

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MANUSCRIPT RECEIVED BY THE EDITOR JULY 28, 1939 (PART 1) AND SEPTEMBER 16, 1939, PARTS (2–4).

JOURNAL OF PALEONTOLOGY, VOL. 14, NO. 4, PP. 378–381, JULY, 1940

PALEONTOLOGICAL NOTES

A FINE ABRASIVE FOR USE IN THIN-SECTIONING

ALFRED R. LOEBLICH, JR.
Walker Museum, University of Chicago

During the course of thin-section work on the Trepostomatous bryozoa, the writer has experimented with various types of abrasives and carborundum stones. Workers generally encounter little difficulty in grinding sections sufficiently thin that the characters are clearly visible to the eye. At this stage the grinding generally is stopped, for fear of ruining the specimen, but it has been found that still thinner sections are much better for photographing and for the study of minute wall structure.

It has been found that the best method for thin-sectioning bryozoa is to use three thick glass plates with successively finer carborundum as the section decreases in thickness. Grinding is initiated with water and carborundum No. 120 or 220 depending on the size of the specimen, the finer (220) being used with the smaller fragments. When the section is less than 1/16 of an inch thick the slide is washed and grinding continued on the second plate with carborundum No. 600. On this plate the section is ground until the structures are clearly visible to the eye, then for the final grinding it is transferred to the third plate. The most satisfactory abrasive for finishing the grinding is Bausch and Lomb's Corundum No. 906. This abrasive is much finer than the common grade sizes of carborundum yet cuts fairly rapidly, leaving a smoother surface than any other type of abrasive used. With this fine abrasive sections can be cut to approximately half the thickness previously possible, with no great danger of losing the section.

A separate beaker of water for washing the slide is used with each plate, in order to eliminate mixing of the grinding powders. When any of the plates becomes slightly concave due to grinding, the plates are shifted for use with the next coarser grinding powder, and a new plate substituted for the finest abrasive. This method makes possible frequent changing of the glass plates with a minimum of cost, and results in a minimum loss of specimens due to concave grinding surfaces.

Although this fine abrasive has been used by students in Walker Museum chiefly in sectioning bryozoa, it has been found equally valuable in polishing surfaces of corals and crinoid roots and should prove an aid in the thin-sectioning of foraminifera. The corundum may be obtained from any dealer in Bausch and Lomb optical equipment.

MANUSCRIPT RECEIVED BY THE EDITOR FEBRUARY 22, 1940.

GENUS LITUOLA IN THE ADAMS OIL DEEP TEST, LAFAYETTE COUNTY, MISSISSIPPI

FREDERIC F. MELLEN
West Point, Mississippi

A recent examination of the cuttings from the Adams Oil & Gas Company's No. 1 Lewellen, a 4185-foot test in Sec. 9, T. 10 S., R. 1 W., Lafayette County, Mississippi, has extended the known areal and stratigraphic distribution of the genus *Lituola* in the state. The abundance of these readily determinable macroscopic arenaceous foraminifera suggest their possible great value as horizon markers in a large part of Mississippi.

The samples at 670–680, and 690–700 feet, showed *L. erecta* Mellen and Gault in the basal Midway Clayton formation, a light-gray very fossiliferous, slightly glauconitic, silty chalk. The Cretaceous-Eocene contact is at 700 feet.

The sample 1450–1460 feet contained an excellent specimen of *L. taylorensis* Cushman and Waters. The position of this sample is within the Mooreville tongue of the Selma chalk, 110 feet below the Coffee sand, and 750 feet below the top of the Cretaceous. As recorded in our paper, *L. taylorensis* had been found in Mississippi only in the lower part of the Prairie Bluff chalk, within 100 feet of the top of the Cretaceous. The discovery of the specimen in lower Selma chalk extends the stratigraphic range to 650 or 700 feet of the younger Upper Cretaceous sediments, although the form is not present at all horizons throughout that range, and notably is missing at the Prairie Bluff (Owl Creek) horizon in the Lewellen well.

Other test wells in north-central Mississippi should be watched for recovery of these forms, which may prove to be useful markers without the necessity of highly technical knowledge or equipment for their determination.

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MANUSCRIPT RECEIVED BY THE EDITOR APRIL 7, 1940.

THE VALUE OF QUANTITATIVE DATA IN MICROSTRATIGRAPHY

S. W. TROMP
Zamalek, Cairo, Egypt

The study of the micro-paleontological data published by scientists of different countries shows the great lack of exact quantitative data in the international literature on micro-stratigraphy. One can almost say that such data are nearly completely missing. During the writer's study of the micro-stratigraphy of Egypt he has always based his age determinations both on qualitative and on quantitative generic determinations.

The different reasons why these generic determinations have been used instead of specific ones have been fully discussed in an article called "The value of generic determinations in micro-stratigraphy" (published in 1939 in "Geologie en Mijnbouw," no. 8, Holland). The main reasons are the following:—

1. Many Foraminifera are often so badly preserved in disintegrated samples, that they do not allow any specific determination, whereas generic determinations might be still possible. In representing the total fauna in a micro-faunal chart these necessarily are gaps in specific determinations, because many Foraminifera which occur in these samples could not be represented.

2. The different species of a certain genus are often strongly influenced by the facies of the rocks in which they occur, and therefore the fluctuations in a species chart often show only facies changes and not stratigraphically significant faunal changes.

3. Most micro-paleontologists are accustomed to plot a few graphs showing the distribution of only those species which occur quite abundantly. Very often many species of a certain genus are found, but only a few specimens of each species. In these cases graphs could not be plotted, whereas if all the species of a certain genus were taken together it is often still possible to plot characteristic graphs.

4. The phenomenon of polymorphism in the Foraminifera has caused and still causes great difficulties if exact specific determinations are to be made.

Quantitative data, to which most micro-paleontologists pay little attention, can be of considerable help in age determinations by means of micro-faunas.

The quantitative studies of disintegrated samples deal with two different kinds of data: Firstly, the amount of small Foraminifera present in a sample and, secondly, the size of the different small Foraminifera. Both will be discussed separately.

The total amount of small Foraminifera in a sample from a geological horizon is never constant and will be greatly influenced by ecological facies, but in general the ratios between the genera, especially if they are closely related, will not change funda-

mentally. If one selects the rocks with the most favorable facies (calcareous clays, calcareous shales or marls) it is possible to establish the maximal amount of Foraminifera present in samples of an outcrop.

In order to compare the different amounts of Foraminifera in samples from the same outcrop or in samples from different outcrops the counting should be based on equal quantities of rock.

If the distribution of Foraminifera were uniform the total amount of rock would be of no importance, but this seldom is the case.

Always the same amount of rock should be used in order to make the "distribution influence" as small as possible. The writer uses 200 gms. of rock, which is disintegrated by crushing and cooking with soda, and is washed with water over four sieves, respectively 0.6, 0.3, 0.15, and 0.075 mm. mesh, or 0.6, 0.3, 0.2, 0.1 mm. mesh.

The reasons for the separation will be given later. It would require too much time to count all the Foraminifera present in the whole residue of a disintegrated sample. It is sufficient to study only two spreadings of this residue, spread on a plate with circular or square divisions. After some practice one can make spreadings with equally distributed grains. During the counting only the grains in the same area between the circles (with a radius of about 2.5 cm.) must be taken into consideration.

The fact that more Foraminifera are present in two spreadings of mesh 0.1 mm. than in mesh 0.3 mm. does not prove necessarily that the total amount of foraminifera in the total 0.1 mm. residue is larger than the one in the total 0.3 mm. residue, because from the 0.3 mm. residue it might be possible to cover a larger total area than from the 0.1 mm. residue, But the praxis shows that one can cover a greater area from a 0.1 mm. residue than from the same weight of a 0.3 mm. residue. In other words the possibility discussed is only a theoretical one. The most accurate solution would be of course to estimate for each residue how many spreadings can be made, but also in this case the praxis shows that it is unnecessary and that one tries to be more accurate than is necessary for the purpose. If 200 gms. of rock are used and the total amount of Foraminifera present in two spreadings of the residue left on each sieve is counted, it is possible to compare samples from the same and different outcrops with sufficient accuracy.

As stated before accurate quantitative data are rarely published. Neither the quantity of rock nor the method of counting is mentioned. The only quantitative data one finds are terms like sparsely, frequent, abundant etc., but it is impossible to know exactly what is meant with these expressions. The writer uses only the following expressions: Very rare (1–5 forams in 2 spreadings), rare (6–10 in 2 spreadings), abundant (101–1000 in 2 spreadings) and flooded (>1000 in 2 spreadings). These group divisions have proved to be sufficient for stratigraphic purposes, because it does not make any difference if a sample contains 300 or 400 forams. Only amounts like 200 to 900 or more than 1000 showed to be of great importance and it is based on practical experience that only those 5 group divisions were made. The quantitative data are used for two different purposes:

To calculate the exact ratios between related genera, and to study the decrease or increase in abundance of a certain genus during different geological periods.

The first application is of special interest in the Globigerinidae. The exact *Globigerina-Globigerinella* ratio, *Globigerinella-Globigerinoides* ratio etc. showed to be of great importance in stratigraphical work in Egypt both for Cretaceous and Tertiary sediments.

The second mentioned application is especially useful if the size of the Foraminifera is considered. The Cretaceous-Eocene contact for example is characterized in Egypt by an enormous decrease in size of the Gümbelinas from the Cretaceous into the Eocene. As far as they are present in the Basal Eocene they occur only in meshes <0.2 mm. The Globorotalias show a reverse situation. They increase suddenly enormously at the base of the Eocene. Many similar examples could be given for the Eocene or younger horizons.

The size of small Foraminifera has always been considered of little importance, because Foraminifera may be developed as microspheric or megalospheric forms. Although theoretically this seems to be the case, in

fact the average size of micro- and megalospheric forms fluctuated during geological time and the size of the Foraminifera therefore is of great importance, especially if the proportion of different size limits is taken into consideration.

It has been mentioned above that samples are washed over 4 sieves with meshes of 0.6, 0.3, 0.15, and 0.075 mm., and that the dried residue of each of these meshes is studied separately. Counting the amount of each of the different genera present in those residues, it is possible to establish the most abundant size grade.

The result of our investigatons shows that a given genus appears first in a stratigraphic section rarely in mesh 0.075 mm.; then the amount in this mesh increases gradually, and finely a few specimens appear in mesh 0.15, gradually also in mesh 0.3, and sometimes even in mesh 0.6. Often this fauna decreases again in size of individual and the same changes in reverse direction can be observed. At the same time that the amount and size of individuals of a certain *genus* increases, the variety of different *species* often increases and should be recorded.

The small size of the Foraminifera on mesh 0.075 mm. makes it difficult to describe this mesh. But the results obtained fully compensate for the difficulties.

One of the results of the use of the fine mesh has been that a few genera are shown to appear earlier in the record than generally supposed. They generally are scarce in the first occurrences, however, and are found only in mesh 0.075 mm.

Another result has been that curves showing the quantitative distribution of specimens of a certain genus in several geological horizons are much more irregular than published curves showing the biological development of certain faunas. The increase of a certain genus does not take place gradually, but with several fluctuations. These fluctuations in the several meshes have proved to be of great importance in microstratigraphy.

MANUSCRIPT RECEIVED BY THE EDITOR FEBRUARY 15, 1940.

JOURNAL OF PALEONTOLOGY, VOL. 14, NO. 4, PP. 382–388, JULY, 1940

SOCIETY RECORDS AND ACTIVITIES

SUMMARIZED MINUTES OF THE FOURTEENTH ANNUAL MEETING OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

The fourteenth annual meeting of the Society of Economic Paleontologists and Mineralogists was held in the Stevens Hotel, Chicago, Illinois, Thursday and Friday, April 11–12, 1940. The meeting was held in conjunction with the regular annual convention of The American Association of Petroleum Geologists.

The Council of the Society held its annual business meeting in the Stevens Hotel, Wednesday, April 10, 1940, at 5:00 P.M. Doctor Gayle Scott, president, called the meeting to order. Council members present were: Gayle Scott, E. H. Sellards, H. B. Stenzel, S. G. Wissler, and the incoming president, Carey Croneis. Messrs. Norman D. Newell, W. H. Twenhofel, and W. C. Krumbein were also present.

The following items of business were discussed:

1. Possibility of increasing the number of plates in the *Journal of Paleontology*.
2. Feasibility of printing a memorial number.
3. Reprinting of Volume I of the *Journal of Paleontology*.
4. Meaning of a "signed ballot."
5. Date of notification of the newly elected members of the Council.

The regular program of the Society began at 9:00 A.M., Thursday, April 11, in the South Ball Room of the Stevens Hotel. The following papers were presented:

THOMAS G. PAYNE, "Recurrent Facies and Faunules of the New York Middle Devonian."

W. FARRIN HOOVER, "A Correlation of the Subsurface Devonian of Sandoval, Illinois, Pool with the Devonian Outcrop in Southwest Illinois."

Announcement by MAYNARD P. WHITE concerning "A Catalogue of Foraminifera," by BROOKS F. ELLIS.

R. L. CLIFTON, "Invertebrate Faunas from the Blaine and the Dog Creek Formation of the Leonard Series."

WILLIAM F. READ, "Association of West Texas Permian Vertebrates and Plants with Marine Invertebrates."

JOHN R. BALL, "Some Silurian Correlations in the Lower Mississippi Drainage Basin."

WILLIAM H. EASTON, "Mid-Carboniferous Strata of Northern Arkansas."

NORMAN D. NEWELL and BERNHARD KUMMEL, "Permo-Triassic Boundary in Southeastern Idaho and Western Wyoming."

LLOYD W. STEPHENSON, "Summary of Faunal Studies of the Navarro Group of Texas."

JULIA GARDNER, "Analysis of the Midway Fauna of the Western Gulf Province."

GROVER MURRAY, JR., "Comparison of the Ostracode Fauna of the Gosport at Claiborne Bluff, Alabama, with Faunas of Known Jackson and Claiborne Localities." (By Title)

MAX B. PAYNE, "Type Moreno Cretaceous and Superjacent Eocene, Panoche Hills, California." (By Title)

EDWARD A. FREDERICKSON, "Cambro-Ordovician Trilobites from Oklahoma."

M. S. CHAPPARS and ALFRED R. LOEBLICH, JR., "The Genus *Constellaria* in North America."

HAROLD B. RENFRO, "Pelecypod Fauna of the Permian Satanka Shale."

CHARLES E. DECKER, "Graptolites from the Haragan Formation (Lower Devonian) of Oklahoma."

NORMAN D. NEWELL, "Phylogeny of *Myalina* s.s."

HEINZ A. LOEWENSTAMM, "The Development of the Root *Ancyrocrinus*."

R. HENDEE SMITH, "Micropaleontology and Stratigraphy of a Deep Well at Niceville, Okaloosa County, Florida." (By Title)

ALFRED FISCHER, "A Belemnite from the Permian of Greenland."

GROVER MURRAY, JR., and KEITH M. HUSSEY, "Tertiary Ostracoda of the Genera *Alatacythere* and *Brachycythere*." (By Title)

HELEN TAPPAN LOEBLICH, "New Arenaceous Foraminifera from the Woodbine Sand of Northern Texas."

HUBERT G. SCHENCK, "Economically Important Microfossils."

M. L. THOMPSON and J. C. HAZZARD, "Permian Fusulinids from the Providence Mountains, California." (By Title)

M. L. THOMPSON and H. J. BISSELL, "Pennsylvanian and Permian Fusulinids of the Wasatch Mountains, Utah." (By Title)

L. G. HENBEST and S. A. BERTHIAUME, "Fusulinidae from the Crooked River Basin, Oregon."

A. K. MILLER and W. M. FURNISH, "Pennsylvanian Ammonoid Zones in the Northern Mid-Continent Region."

RAYMOND C. MOORE, "Asymmetrical Crinoids with Unbranched Arms." (By Title)

E. C. DAPPLES, "The Sedimentary Characteristics of the Lonsdale Limestone."

N. ALLEN RILEY, "A Simplified Method of Studying the Shapes of Sedimentary Particles."

BENJAMIN H. BURMA, "Statistical Analysis Applied to Fusulinids."

F. J. PETTIJOHN, "Relative Abundance of Size-Grades of Clastic Sediments."

GEORGE H. OTTO, "Field Sampling Errors in Relation to Typical Beaches of Texas, Florida, and California."

GEORGE H. OTTO and MELVIN N. LEVET, "Effect of Sieving Time and Sample Weight on the Statistics of Sieve Analyses of Quartz Sand."

W. M. COGEN, "Heavy Mineral Zones of Louisiana Gulf Coast Sediments."

The program session was adjourned at 11:00 A.M., Friday, April 12, and the Society went into the annual business session, President Scott in the chair.

The minutes of the 1939 meeting were approved and accepted as published in the July, 1939, *Journal of Paleontology.*

The following reports were given:

1. *Research Committee Report.*—Maynard P. White, Chairman.

The main work of the Committee consisted of individual efforts to procure papers for the publications of the Society. It was suggested that those authors less experienced in difficulties of editing, secure someone having more experience to edit their papers before submitting them for publication. It was considered advisable to continue to represent in the makeup of the Committee the different geographic centers of the membership and to rotate tenure. Close cooperation with the Research Committee of the A.A.P.G. was stressed. The need of a comprehensive index of the *Journal of Paleontology* was noted. Lastly, the Committee can look with considerable pride upon the establishment of a permanent organization by the American Museum of Natural History as a department of that institution to publish the Catalogue of Foraminifera; to care for supporting materials; to keep the published catalogue up to date; act as a clearing house for current literature; offer a depository for types and faunas; and staffed to supply information on request. The first of approximately thirty volumes, involving some 30,000 pages of text and illustrative material, dealing with some 15,000 genera and species covering all works on Foraminifera up to 1938, will come off the press in July, 1940, to be followed by four volumes a month until completion.

2. *Report of the Editor of the Journal of Sedimentary Petrology.*—Doctor W. H. Twenhofel appealed to the S.E.P.M. membership to submit articles for publication in the *Journal of Sedimentary Petrology* so that the greater number of the articles published would not be from non-members.

3. *Report of the Editor of the Journal of Paleontology.*—Doctor Norman D. Newell reviewed the progress of the *Journal of Paleontology* and stressed the importance of securing new members and subscribers to the *Journal.* He recommended that contacts be made with heads of geological departments and teachers of geology suggesting that they interview their students explaining the advantages of associating themselves with the Society.

4. *Report of the Secretary-Treasurer.*—Doctor H. B. Stenzel read the following records:

FINANCIAL STATEMENT, 1939

To the Council,
Society of Economic Paleontologists and Mineralogists,
Tulsa, Oklahoma

DEAR SIRS:

We have made an examination of the accounting records of the SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS for the year ended December 31, 1939 and now submit our report, thereon, together with the following statements.

Exhibit
- *A* Statement of Financial Condition, December 31, 1939
- *B* Statement of Income for the year ended December 31, 1939

Schedule
- 1 Statement of Receipts and Disbursements for the year ended December 31, 1939

In connection with our examination, we reviewed the system of internal control and accounting procedures of the Society and, without making a detailed audit of the transactions, have examined or tested accounting records of the Society and other supporting evidence, by methods and to the extent we deemed appropriate.

Demand and savings deposits were reconciled to certificates received directly from the depositories. Inventory of publications represents approximately 26,400 *Journals* (exclusive of *Journals* in excess of complete sets for issues prior to 1939) as shown by the records, including certain issues printed at the expense of the Paleontological Society for the years 1935 to 1939, inclusive, stated at appraised values of fifty cents each for *Journals* printed prior to 1939 or cost to either the Society of Economic Paleontologists and Mineralogists or the Paleontological Society for *Journals* printed in 1939. We made extensive tests of quantities and computations.

The Society of Economic Paleontologists and Mineralogists has agreed to distribute a portion of its income to the Paleontological Society. For the years 1938 and 1939 the amounts accruing to the Paleontological Society were $324.82 and $395.23, respectively; the former amount has been charged to surplus and the latter amount has been deducted from current income.

In our opinion, the accompanying statement of financial condition and related statement of income present fairly the position of the Society of Economic Paleontologists and Mineralogists at December 31, 1939, and the results of its operations for the year, in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year.

(Signed) ARTHUR YOUNG & COMPANY, *Accountants and Auditors*
TULSA, OKLAHOMA
February 5, 1940

EXHIBIT A

STATEMENT OF FINANCIAL CONDITION
DECEMBER 31, 1939

ASSETS

CURRENT ASSETS:		
Demand deposits—		
The First National Bank and Trust Company, Tulsa, Oklahoma	$ 4,200.54	
National Bank of Commerce, Tulsa, Oklahoma	49.86	$ 4,250.40
Savings deposits—		
The First National Bank and Trust Company, Tulsa, Oklahoma		1,043.93
Accounts receivable—		
Printed matter (less reserve $58.26)	$ 140.04	
Advertising	56.24	196.28
Inventory of publications—see report		13,768.74
TOTAL CURRENT ASSETS		$19,259.35
FURNITURE AND FIXTURES	$ 482.60	
Less: Reserve for depreciation	95.94	386.66
PREPAID AND DEFERRED CHARGES		557.06
TOTAL ASSETS		$20,203.07

LIABILITIES AND SURPLUS

CURRENT LIABILITIES:		
Accounts payable		$ 350.99
Accrued printer's charges		557.06
Amount due to Paleontological Society		395.23
TOTAL CURRENT LIABILITIES		$ 1,303.28
DEFERRED INCOME:		
Subscriptions to Journals	$ 1,201.05	
Membership dues for 1940	646.00	1,847.05

SURPLUS:			
Balance, December 31, 1938		$16,762.24	
Less: Proportion of 1938 income distributed to Paleontological Society		324.82	
		$16,437.42	
Net income for the year ended December 31, 1939—Exhibit B		615.32	
Balance, December 31, 1939			17,052.74
CONTINGENT LIABILITIES:			
All known liabilities of the Society at December 31, 1939, were recorded in the accounts and no litigation was pending at that date			
TOTAL LIABILITIES AND SURPLUS			$20,203.07

EXHIBIT B

STATEMENT OF INCOME FOR THE YEAR ENDED DECEMBER 31, 1939

INCOME:			
Dues and subscriptions—			
Journals of Paleontology and *Sedimentary Petrology*		$ 756.00	
Journal of Paleontology		3,025.50	
Journal of Sedimentary Petrology		918.50	$ 4,700.00
Sales of back numbers—			
Journal of Paleontology		$1,112.60	
Journal of Sedimentary Petrology		382.74	1,495.34
Sales of plates and reprints			273.67
Advertising			210.66
Interest on savings deposit			16.32
Other income			75.31
TOTAL INCOME			$ 6,771.30
Less: Proportion of income accrued to Paleontological Society			395.23
			$ 6,376.07
COSTS AND EXPENSES:			
Printing expenses—			
Journal of Paleontology	$2,745.70		
Journal of Sedimentary Petrology	887.67	$3,633.37	
Reprints		28.67	
Postage and mailing		509.74	
Office rent		300.00	
Clerical salaries		660.00	
Audit expense		100.00	
Office supplies and expenses		128.28	
Depreciation		48.26	
Bad debts		134.71	
Other costs and expenses		69.03	
		$5,612.06	
Decrease in inventory of publications		148.69	5,760.75
NET INCOME			$ 615.32

SCHEDULE 1

STATEMENT OF RECEIPTS AND DISBURSEMENTS FOR THE YEAR ENDED DECEMBER 31, 1939

DEMAND DEPOSITS, DECEMBER 31, 1938			$ 3,269.88
RECEIPTS:			
Membership dues and subscriptions—			
Year 1939—			
Journals of Paleontology and *Sedimentary Petrology*	$ 456.00		
Journal of Paleontology	1,853.84		
Journal of Sedimentary Petrology	531.49	$2,841.33	
Year 1940—			
Journals of Paleontology and *Sedimentary Petrology*	$ 296.00		
Journal of Paleontology	1,121.50		
Journal of Sedimentary Petrology	337.50	1,755.00	
Accounts receivable		170.76	
Sales of back numbers—			
Journal of Paleontology	$1,049.65		
Journal of Sedimentary Petrology	372.90	1,422.55	
Sales of plates		148.89	
Miscellaneous		512.70	6,851.23
			$10,121.11
DISBURSEMENTS:			
Printing expenses—			
Journal of Paleontology	$1,980.00		
Journal of Sedimentary Petrology	516.26		
Engraving *Journal of Paleontology*	605.70	$3,101.96	
Accounts payable		291.06	
Payment to Paleontological Society		324.82	
Editorial salaries		240.00	
Clerical salaries		660.00	
Audit expense		100.00	
Office supplies and expenses		63.16	
Postage and mailing		509.74	
Office rent		300.00	
Refunds on subscriptions		67.61	
Miscellaneous		212.36	5,870.71
DEMAND DEPOSITS, DECEMBER 31, 1939			$ 4,250.40

SUBJECT TO COMMENTS IN ACCOMPANYING REPORT

SPECIAL SALES

March 1, 1939–March 1, 1940

Back Volumes of *Journal of Paleontology*	$967.00
Back volumes of *Journal of Sedimentary Petrology*	$206.50

PRINTING AND ENGRAVING BILLS FOR 1939

JOURNAL OF PALEONTOLOGY

	Banta Printing Bills	*Meriden Engraving Bills (2% Cash Deducted)*	*Total Printing and Engraving Bills*	*S.E.P.M. Total Printing and Engraving Bills*
Number 1 (January)*	$ 990.11	$ 331.90	$1,322.01	
Number 2 (March)	732.57	208.40	940.97	$ 940.97
Number 3 (May)*	824.59	230.27	1,054.86	
Number 4 (July)	662.38	240.56	902.94	902.94
Number 5 (September)*	515.73	236.55	752.28	
Number 6 (November)	674.19	156.74	830.93	830.93
	$4,399.57	$1,404.42	$5,803.99	$2,674.84
(1938 Totals)	($3,825.44)	($1,366.01)	($5,191.45)	($2,401.79)

*Odd Numbers paid for by Paleontological Society.

JOURNAL OF SEDIMENTARY PETROLOGY

	Banta Printing Bill
Number 1 (April)	$ 271.67
Number 2 (August)	284.88
Number 3 (December)	292.15
	$ 848.70
(1938 Total)	($ 800.22)

	1940	1939	1938
1. S.E.P.M. Membership (March 1, 1940):			
Active Members	239	234	206
Associate Members	79	79	81
Total	318	313	287
2. *Journal of Paleontology* Mailing List:			
S.E.P.M. Active Members	214	201	188
S.E.P.M. Associate Members	50	52	55
S.E.P.M. Subscribers	280	340	318
P.S. Members	370	345	348
Total	914	938	909
3. *Journal of Sedimentary Petrology* Mailing List:			
Active Members	109	108	113
Associate Members	19	19	
Subscribers	262	260	227
Total	390	387	340
4. Number of pages in *Journal of Paleontology* (Exclusive of advertising pages and cover)		632	620
5. Number of Plates in *Journal of Paleontology*		69	69
6. Total Edition of *Journal of Paleontology*		1,300	1,300
7. Number of pages in *Journal of Sedimentary Petrology*		136	114
8. Total Edition of *Journal of Sedimentary Petrology*		500	500
New Members from March 1, 1939, to March 1, 1940 (March 1, 1938 to March 1, 1939—30)			9
New Associates from March 1, 1939, to March 1, 1940) (March 1, 1938. to March 1, 1939—17)			11
Transfers to Active Membership from March 1, 1939, to March 1, 1940 (March 1, 1938 to March 1, 1939—14)			12

Doctor Scott expressed his appreciation for the complete cooperation of all Council members during the year, to the several Society members for their responses to requests made during the year, and especially to Doctor W. C. Krumbein, of the University of Chicago, for his very efficient handling of the technical program for the Convention.

The following officers for the year 1940–1941 were announced:

President—Carey Croneis
Vice-President—John R. Sandidge
Secretary-Treasurer—H. B. Stenzel

The meeting adjourned at 12:00 Noon, Friday, April 12 1940.

NOTICES

The National Library of Peking in China is financially unable to continue its subscription to the *Journal of Paleontology*. A proposal has come from the librarian that the Journal be exchanged for an equivalent number of Chinese publications in geology. The Society of Economic Paleontologists and Mineralogists has no depository where exchange material could be made available to the members of the Society. Perhaps some individual would be willing to pay the subscription price for our Chinese colleagues or promote an exchange with the National Library of Peking.

The Works Project Administration, 1734 New York Avenue, N. W., Washington, D. C., announces the release of volume three of the "Index of Research Projects." Only a limited edition has been printed. Subjects are adequately classified so that research projects of interest to geologists can quickly be located.

REVIEWS

HANDBUCH DER PALÄOZOOLOGIE, edited by O. H. Schindewolf, Band 2 A, *partim*, Conularida by B. Bouček. Berlin, Gebrüder Borntraeger, 1939.

Band 2 A of the *Handbuch* consists of one *lieferung* in which the Hydrozoa are treated by Othmar Kühn, the Scyphozoa by A. Kieslinger and the Conularida by B. Bouček. It is with Bouček's summary of the Conularida that this review will deal.

The *Conularida* is treated tentatively as an Order? of Coelenterata in accordance with Kiederlen's suggestion that it may be referable to the Class Scyphozoa. In this connection, it is interesting to note parenthetically that Kieslinger in his treatment of the Scyphozoa in this same volume, notices the Conularians as of uncertain position and seems unimpressed by Kiederlen's arguments, although he accepts as probable Scyphozoans a series of forms (Brooksellidae) which, in the reviewer's opinion, are much less likely to be properly placed in that group than are the Conularida.

Bouček includes in the Conularida extinct marine animals with a chitinous, tubular or pyramidal shell with bilateral or more commonly radial symmetry. The families included are the Conularidae, Conulariellidae, and Serpulitidae (new name). Excluded are several problematical forms often associated with the Conularida. The author's reasons for his exclusions are stated rather briefly.

After the brief introduction of less than a page, each of the three families is taken up. Each is treated under two headings (1) Morphology, which in this part of the work is limited to shell morphology, and (2) Systematics. Under the heading Systematics, genera and subgenera are described. Several problematical genera are treated under a separate heading. Genotypes are cited in all cases, and the majority of the genera are illustrated. Defects are that all of the genera are not illustrated, and none of the genotype citations are documented. Also, some of the generic names employed and in synonymy are undated.

Next, there is presented a brief summary of opinions of various authorities on the systematic relationship of the Conularida with special emphasis on the recent suggestion of Kiederlen's[1] that its relationship is to the Scyphozoa. This is followed by a consideration of reconstructions of the soft parts in which Kiderlen's recent ideas are again given prominence. Finally, there is a page of discussion of the phylogeny within the group.

The reviewer was a little disappointed in the treatment given this interesting group, and was left with the feeling that the principal difficulty was possibly that the editors had assigned too little space to it. It occupies only nineteen pages, three pages more than a signature.

J. BROOKES KNIGHT

DIE FOSSILEN AMPHIBIEN, by O. Kuhn. 98 pp. 79 figs. Berlin, Gebrüder Borntraeger. 1939.

In recent years Dr. Kuhn has been engaged in extensive bibliographic work for the Junk "Fossilium Catalogus." This little volume, like his previous one on fossil reptiles, is a by-product of his bibliographic activity. One third of the text is devoted to general topics—origin of amphibia, a scheme of classification, adaptations, a brief outline of osteology. The remainder consists of a group-by-group treatment of fossil forms.

A series of 79 illustrations is given, which are, on the whole, well chosen and drawn mainly from the most recent sources. In passing, however, one may make one criticism regarding the figures, namely, that many of them are incorrectly credited to secondary sources rather than to their true authors. For example, Broom's familiar pictures of the *Eryops* skull and jaw are attributed to Säve-Söderbergh, a characteristic Williston wash drawing of *Diplocaulus* is stated to be Jaekel's, and the reviewer is, to his embarrassment, credited with the authorship of Gregory's modification of the Watson restoration of *Eogyrinus*.

In no group of tetrapods is the problem of phylogeny so acute or the proper system of

[1] Die Conularien. Über Bau und Leben der ersten Scyphozoa. Neues Jb. f. mineral. Usw., Beil.-Bd. 77, Abt. B., Stuttgart, 1937.

classification so uncertain as in the Amphibia. It is of interest to see what sort of view Kuhn, as a reader of the literature, essentially a "neutral observer," gains of the situation. His account is, on the whole, a rather well-executed attempt to make an orderly arrangement out of the disorderly and shifting picture.

Half of his systematic account is devoted to that most important of fossil groups, the Labyrinthodontia (one is glad to see that the archaic and meaningless term "stegocephalia," still surviving in the more old-fashioned texts of geology and zoology does not appear. Here the treatment in general follows the scheme laid down in Watson's classic papers of 1919 and 1926. His morphological "grades," Embolomeri, Rhachitomi and Stereospondyli are used as subordinal terms and the family arrangement is based essentially on Watson's determinations. Kuhn's text, however, reflects some of the complications that arise from fresh discoveries when one attempts to apply Watson's evolutionary scheme in too strict a fashion. Evidence has arisen which tends to suggest that the family tree of the labyrinthodonts (as that of many other groups) may be in reality a bush, and that the Rhachitomi and Stereospondyls may be polyphyletic, as Watson himself, in his choice of terms, tends to suggest. Further, Watson's belief that all, or nearly all, the Carboniferous labyrinthodonts were embolomeres is becoming increasingly open to question. In point of fact only three Carboniferous Amphibia are actually known to possess embolomerous vertebrae, and in America, at least, rhachitomous amphibians were already present in the Stephanian and even in the Westphalian. Still further, even morphological "grades" are no longer clearly separable geologically; for example, the rhachitomous type of palate, supposedly characteristic of the Permian, is present in a number of Carboniferous labyrinthodonts. It is clear that much of interest remains to be discovered concerning labyrinthodont phylogeny.

In Kuhn's classification the Order Phyllospondyli, of which the branchiosaurs are the central type, appears to be a large and important one, including a great variety of paleozoic genera ranged in six families. But at the present time it appears almost certain that no such group exists, and that the supposed "phyllospondyls" are all labyrinthodonts. This contradiction is no criticism of Kuhn, for his systematic treatment reflects the beliefs current in publications during the 1930's. "The Rise, Decline and Fall of the Phyllospondyls" is a scientific comedy in which the reviewer pleads guilty of having (with Watson and Steen) played an embarrassingly prominent role. Because of faulty basic assumptions the Order Phyllospondyli grew by gradual accretions to considerable size only to collapse under its own weight. This story has been summarized by the reviewer in a recent number of the American Journal of Science and need not be repeated here.

When he comes to a discussion of the remaining small paleozoic amphibians, Kuhn betrays some uncertainty, and not unreasonably, for the classification of these forms is in a most confused state. In one regard they all contrast strongly with the labyrinthodonts, for the centrum is in every case a single spool-shaped structure in which there is no evidence of arcualia and in which ossification appears to have occurred in or around the chordal sheath. For these forms Zittel coined the term Lepospondyli. Within the lepospondyls there are two groups which appear to be fairly distinct and clean-cut, the Nectridia (including *Diplocaulus* and other "horned" types and the elongate urocordylids) and (rather less clearly definable) the snake-like Aistopoda. There still remains a welter of small, varied and more or less obscure forms, particularly prominent in the Nyran fauna of Fritsch (recently redescribed ably by Steen). Dawson's term Microsauria was founded on one of these types and in the amended form Micramphibia has been used by the reviewer, as a third suborder of the Lepospondyli, to cover most of them. Kuhn retains the nectridians and aistopods in the Lepospondyli, but places part, at least, of the "Microsaurs" in the separate Order Adelospondyli. This name was invented by Watson a decade ago to include *Lysorophus* and a few seemingly related types. The presence of a suture between neural arch and vertebral centrum was cited as a diagnostic character. Later work, however, has shown that this suture

is visible in some specimens, at least, in a wide variety of types, including *Microbrachis*, *Hylonomus*, the type genus of the Microsaurs, and the *Gymnarthrus* group (Price, in press). One tends to suspect that the presence or absence of the suture is, as in many reptiles, nothing but an indication of age, and that the term Adelospondyli is essentially a synonym of Microsauria. Kuhn's treatment of the existing orders—Anura, Urodela, Coecilia—is necessarily brief, because of the paucity of fossil material. He has been able to include an account of the recent discovery of the archaic frog *Protobatrachus* from the Lower Trias of Madagascar. This form, as Kuhn points out, allows interesting comparisons to be made between the Anura and Labyrinthodontia. Professor Watson informs me that unpublished work of his on Carboniferous forms tends strongly to confirm the labyrinthodont ancestry of the Anura.

Kuhn has little to say with regard to the ancestry of the Coecilia and Urodela. Morphological evidence has for some time suggested to the reviewer that both have been derived from microsaurian lepospondyls: the coecilians from the lysorophid group, the urodeles from some less specialized forms (Price's studies suggest that the gymnarthrids approximate this type).

Instead of the seven orders listed by Kuhn, the Amphibia may perhaps be ranged in five groups constituting two series as follows: Series A. Arcualia primitively prominent in centra.

Labyrinthodontia (incl. "phyllospondyls")
Anura.

Series B. Holospondylous perichordal centra.

Lepospondyli (incl. Netcridia, Aistopoda, Microsauria)
Urodela
Coecilia

The suggested arrangement implies an early dichotomy of the amphibian stock. But the common features found abundantly throughout the body in all amphibians render absurd such suggestions as one recently made that the urodeles are, in contrast to other tetrapods, descendants of the specialized lung-fish group.

Kuhn's book gives a faithful summary of the state of amphibian paleontology in the 1930's. But so rapidly is the picture shifting that this portrayal is essentially one of historic rather than current interest. Above I have suggested alternative interpretations which I believe are more in accord with present knowledge. But these too may in a short time prove to be outmoded.

A. S. ROMER

A National Research Council—A.A.P.G. Book

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